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ARE WE ALONE IN THE SOLAR SYSTEM?

How NASA-led research has revealed a surprising answer

Why we're hunting for
QUARK STARS

BEATING CLIMATE CHANGE *FROM SPACE*

NASA'S NEW MISSION
JOURNEY TO THE CENTRE OF MARS

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InSight is due to launch on 5 May and will reveal more about Mars' interior

@ Adrian Mann

Welcome

Are we alone in the Solar System? Whether we're able to answer the question with a resounding yes or no is still a flabbergasting concept. If we are – and even extremophiles are nowhere to be found in our solar neighbourhood – then where does that leave us in the hunt for life in planetary systems beyond ours? If we aren't alone, then there's myriad questions to be answered: what's this newly uncovered lifeform like? Are we able to communicate with it? Could we live together in the Solar System without us contaminating its world while we go about our studies of its planet or moon? As you'll discover on page 16, scientists from NASA, ESA and elsewhere have some thoughts about that – what's more, they've pinpointed the destinations on our side of the galaxy where life is likely to exist and how we're going to go about sniffing them out.

If you've always wanted to discover a comet, see a star explode before everyone else, find an exoplanet or uncover a new asteroid, then you're in luck: astronomers who have done just that have shared their secrets, tips and tricks in making that groundbreaking discovery from your back garden.

Looking for your next piece of kit? Don't forget to take advantage of our fantastic new offer where we're giving away free Kepler GL 10x50 binoculars when you subscribe to the magazine. Head to page 34!

Gemma Lavender
Editor

"Analysis of these [seismic] waves will allow us to create a 3D picture of the inside of the planet" **Dr Bruce Banerdt, Page 26**

Our contributors include...

Giles Sparrow
Author & astronomer
Giles reveals the steps we're taking to find out if we're really alone in our solar neighbourhood. Turn to page 16 to find out how we'll get the answer once and for all.

Ian Evenden
Science & technology writer
Your flight into space could be sooner than you think! Ian reveals the places we're building space ports and what to expect during the ride.

Lee Cavendish
Staff Writer & astronomer
NASA's new Mars mission InSight is due for launch – Lee caught up with the mission's scientists to find out what you need to know.

Libby Plummer
Science & technology journalist
Head to page 50 for Libby's report on how we're combating climate change from Earth orbit – from ESA satellites to our intended action plan.

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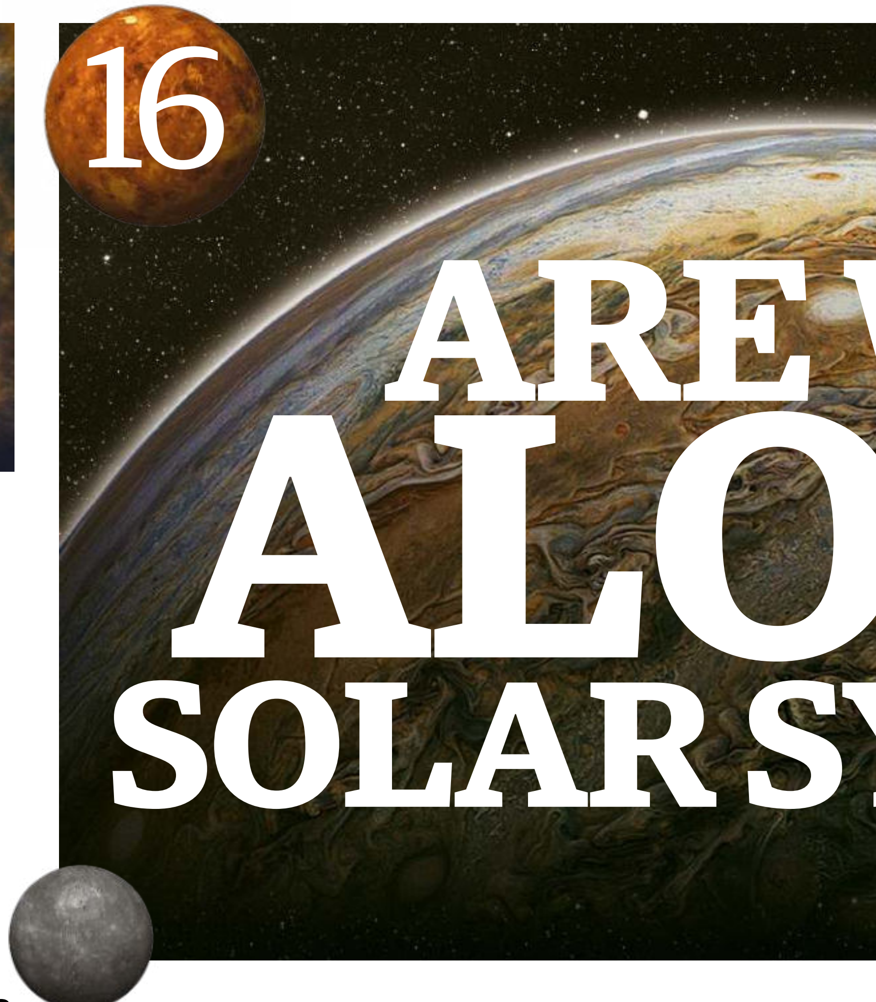

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"No one ever wakes up in the morning and says, 'I hate the universe'"

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Space hangout

Hanging off the International Space Station, NASA astronaut Drew Feustel is in the middle of installing wireless communications antennae on the station's Tranquility module. During his spacewalk with fellow NASA astronaut Ricky Arnold, which took place during late March, Feustel took the opportunity to replace a camera system and remove suspect hoses from a cooling system while being safely tethered to the Earth-orbiting platform throughout the six-hour, ten-minute task.

When all was done and dusted, the astronauts checked over their spacesuits and gave the Quest airlock – the pressurised module which serves as a stowage area for hardware and a staging area for crewmembers getting ready to go into space – a clean.

Expedition 55 Soyuz Commander Oleg Artemyev of Roscosmos and NASA astronauts Ricky Arnold and Drew Feustel launched into space on 21 March on board a Soyuz MS-08


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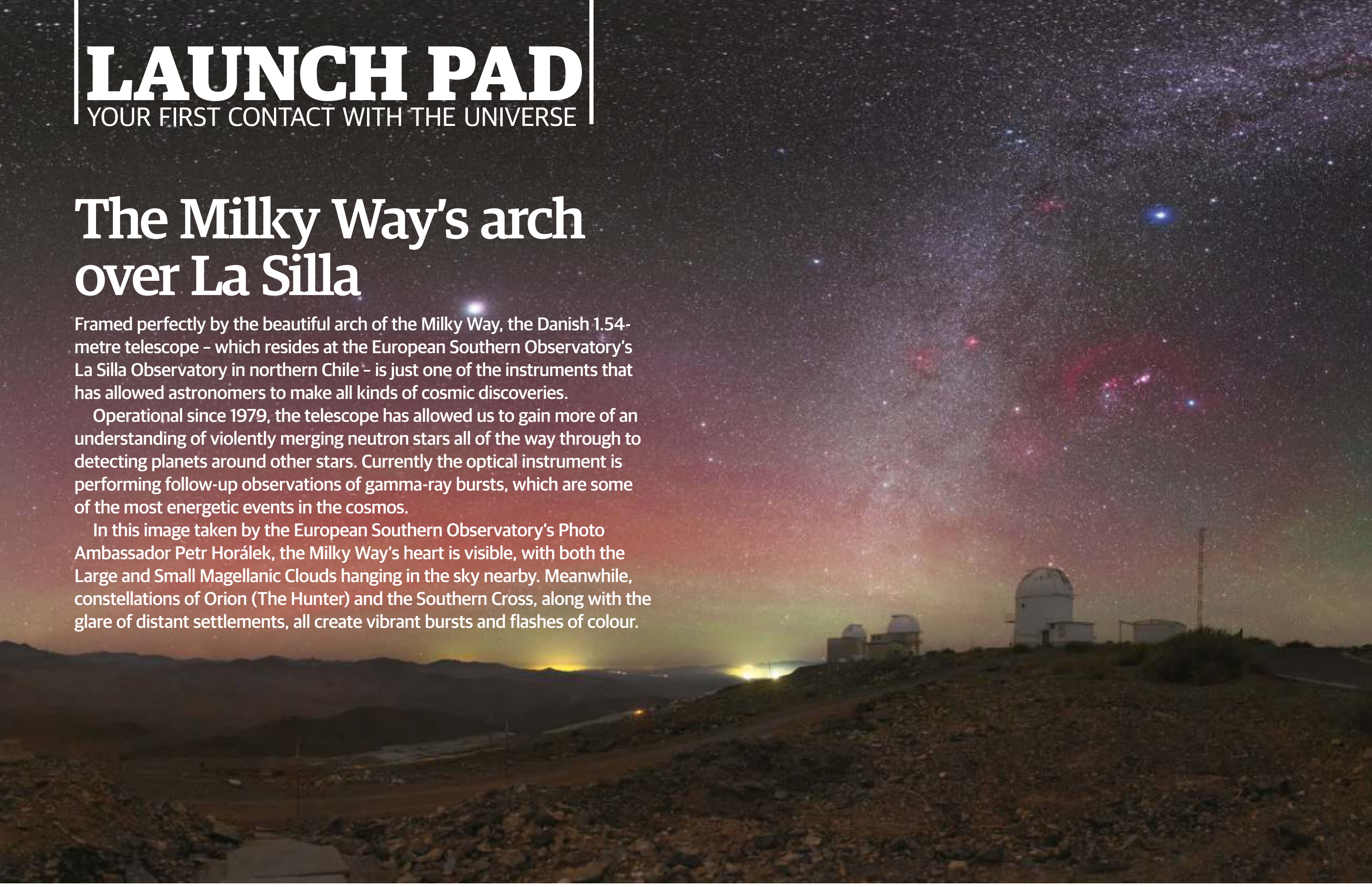

The Milky Way's arch over La Silla

Framed perfectly by the beautiful arch of the Milky Way, the Danish 1.54-metre telescope – which resides at the European Southern Observatory's La Silla Observatory in northern Chile – is just one of the instruments that has allowed astronomers to make all kinds of cosmic discoveries.

Operational since 1979, the telescope has allowed us to gain more of an understanding of violently merging neutron stars all of the way through to detecting planets around other stars. Currently the optical instrument is performing follow-up observations of gamma-ray bursts, which are some of the most energetic events in the cosmos.

In this image taken by the European Southern Observatory's Photo Ambassador Petr Horálek, the Milky Way's heart is visible, with both the Large and Small Magellanic Clouds hanging in the sky nearby. Meanwhile, constellations of Orion (The Hunter) and the Southern Cross, along with the glare of distant settlements, all create vibrant bursts and flashes of colour.

Chaotic web of galactic star birth

This recently released stunning scene captured by the European Space Agency's Herschel Space Observatory reveals the true complexity of our galaxy, the Milky Way. To the human eye our galaxy appears as an impressive collection of stars, but to the far-infrared eyes of the now-defunct spacecraft, intricate networks of gas filaments and dark bubbles are revealed, interspersed by exceedingly bright hotspots where new, baby stars spring to life. Cooler regions are displayed in a red-brownish colour, while hotter regions – where star formation is much more intense – dazzle in blue and white overtones. Look closely and you'll be able to make out the chaotic web of gas filaments – it's thought that the there's a link between star formation and the structures filling the interstellar medium. The densest strands become unstable, forming clumps of material tied together by gravity.

©ESA

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Echoes of far away light

A unique shot taken by the European Southern Observatory's VLT Survey Telescope (VST) uncovers two galaxies right at the beginning of the merging process. The smash up between the duo has created a rare effect known as a light echo, where light bounces off the material within each galaxy. The effect is analogous to the acoustic echo where reflected sound arrives at the listener with a delay after the sound is emitted.

The larger galaxy of the two is seen here in yellow and is known as ShaSS 073. It's an active galaxy with an extremely luminous, highly energetic core. Meanwhile, its less massive companion, named ShaSS 622, glows in blue and completes the intriguing ShaSS 622-073 system. The pairing's radiation causes a bright glow as it absorbs and then re-emits light, extending across 1.8 billion square light years.

While studying the merger, astronomers discovered that the luminosity of the large central galaxy is 20-times lower than required to excite the gas in this way – an indication that the centre of ShaSS 073 has faded dramatically over the last 30,000 years or so.

© ESO

© NASA

NASA transforms aviation

It might be an artist's concept at the moment, but NASA's new Low-boom Flight Demonstration X-plane – which has recently been given the go ahead for construction – is set to revolutionise travel and is designed to fly faster than sound with the latest in quiet supersonic technologies.

"It is super exciting to be back designing and flying X-planes at this scale," says Jaiwon Shin, NASA's associate administrator for aeronautics. "Our long tradition of solving the technical barriers of supersonic flight to benefit everyone continues."

The key to success for this mission will be to demonstrate the ability to fly supersonic while generating sonic booms so quiet that people on the ground will hardly notice them – that is, if they even hear them at all.

Meet Steve

This strange shimmering ribbon of purple light, which was discovered in 2016, is known as Steve. It's a weird feature of the aurora which has mystified astronomers for quite some time, but now – thanks to the European Space Agency's Swarm mission – more is known about this strange phenomenon.

Researchers were first made aware of Steve when members of the Aurora Chasers Facebook group started posting photos of unusual streaks in the night sky. Aurorae are made when our magnetic field guides energy and atomic particles in the solar wind around Earth and towards the north and south poles. When these particles crash into the atoms and molecules of the upper atmosphere, waves of luminous green light of the aurora borealis and aurora australis appear.

While Steve can appear at the same time as an aurora, it's found to be quite a different beast. While standard aurorae paint the sky in greens, blues and reds and can last for hours, Steve remains in the sky for a relatively short time.

Steve's made through the same general process as a normal aurora, travelling along different magnetic field lines and appearing at much lower latitudes.

New view of the Orion Nebula

Brand-new data from the Atacama Large Millimeter/submillimeter Array (ALMA), as well as other telescopes, has been used to create this stunning image that reveals web filaments in the Orion Nebula. They might look fiery and red-hot, but in reality they are so cold that only telescopes that operate in millimetre-wavelengths are able to observe them.

The Orion Nebula lies about 1,350 light years away from Earth, with this snap in particular combining data not just from ALMA but from the IRAM 30-metre telescope (red) and the European Southern Observatory's HAWK-I instrument (blue). The grouping of bright blue-white stars, visible in the upper left, is the Trapezium Cluster, which is made up of searing hot, young stars only a few million years old.

Earth-orbit view of Egg Island, Bahamas

The European Space Agency's Copernicus Sentinel-2B spacecraft snapped this gorgeous image of Egg Island in the tropical Bahamas. Covering some 800 square metres, Egg Island is officially known as an islet, a tiny uninhabited patch at the northwest end of the long thin chain of islands that make up the Eleuthera archipelago, some 70 kilometres (43 miles) from Nassau. The small island's name is thought to originate from the seabird eggs collected there.

The image was snapped by the Earth-observation spacecraft in early February 2018, revealing the sharp contrast between the stunning shallow turquoise waters to the southwest and the deeper, darker Atlantic waters to the northeast. Ripples of sand waves seen to the bottom of the shot are created by currents and stand out in the shallow waters.

Hubble captures farthest star ever seen

The blue supergiant Icarus is spied more than 9 billion light years from Earth in an astonishing discovery

"This is the first time we're seeing a magnified, individual star"

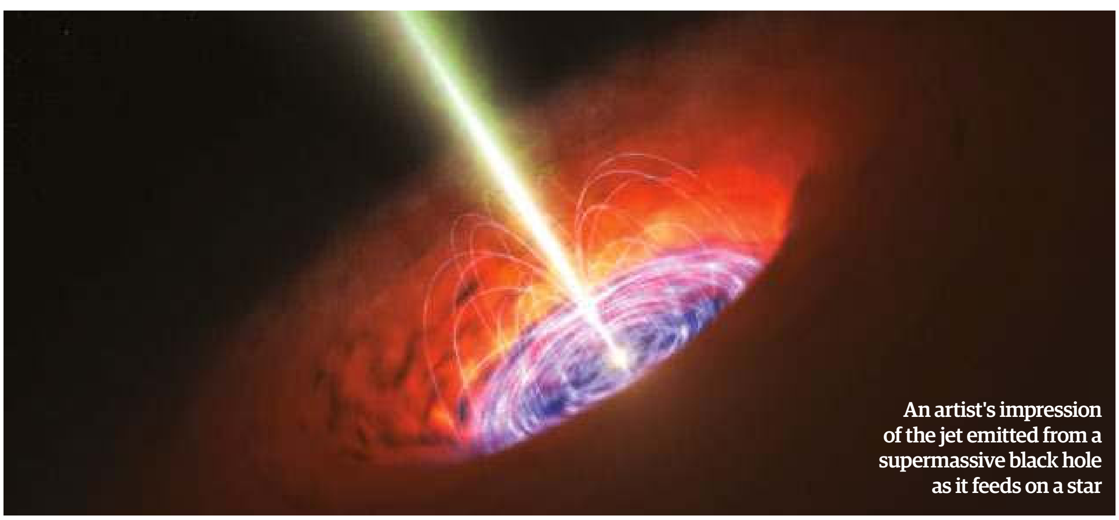
This composite shows the location of the most distant known star, detected using Hubble

Distant black hole spotted shredding a star

Black holes may emit energy in proportion to the amount of stellar material they consume

A black hole situated more than a billion light years away has torn up and devoured a star, allowing astronomers to gain a deeper insight into the workings of such celestial objects. Scientists have been studying emissions from the supermassive black hole and they have found a proportional link between the X-rays that are produced by stellar material falling into the hole and the jet of energy that is emitted. It gives clues as to how black holes devour matter and regulate the growth of galaxies.

The findings relate to radio signals picked up in November 2014 from 300 million light years away. Scientists found that the signals matched closely with X-ray emissions produced from a flare 13 days earlier. Such radio echoes are considered to be more than coincidence, indicating some kind of burp. It suggests black hole jets are powered by the accretion rates and it is the first time scientists have been able to observe it from a single event.



An artist's impression of the jet emitted from a supermassive black hole as it feeds on a star

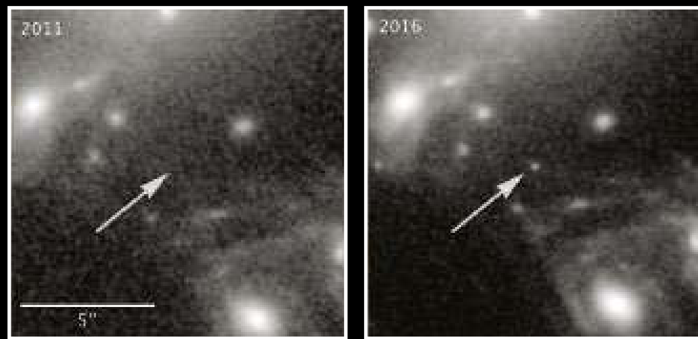
"This is telling us the black hole feeding rate is controlling the strength of the jet it produces," says Dheeraj Pasham, a postdoc at MIT's Kavli Institute. "A well-fed black hole produces a strong jet, while a malnourished black hole produces a weak jet or no jet at all. This is the first time we've seen a jet that's controlled by a feeding supermassive black hole."

The results will help astronomers work out the physics of jet behaviour, which is essential in modelling the evolution of galaxies. "If the rate at which the black hole is feeding is proportional to the rate at which it's pumping out energy, and if that really works for every black hole, it's a simple prescription you can use in simulations of galaxy evolution," says Pasham.

Astronomers using NASA's Hubble Space Telescope have detected the most distant star ever viewed. The enormous blue star, which has been nicknamed Icarus, is as much as a million-times more luminous and twice as hot as our Sun. It is located in a very distant spiral galaxy and it is so far away that its light would have taken a staggering 9 billion years to reach Earth.

According to the team leading the discovery, the blue supergiant appears to us as it did when the universe was about 30 per cent of its current age, and it is more than 100-times further away than the next individual star to have been studied. "This is the first time we're seeing a magnified, individual star," says study leader Patrick Kelly, a former University of California at Berkeley postdoc who now works at the University of Minnesota, Twin Cities.

The find came as the team was monitoring a supernova in the spiral galaxy, and was made possible thanks to gravitational lensing, a quirk of nature that acts to amplify the star's feeble glow. Gravity from a massive foreground cluster of



galaxies called MACS J1149+2223 acts as a natural lens, bending and amplifying light. Situated 5 million light years from Earth, the cluster sits between our planet and Icarus, and it allowed for a better - albeit fleeting - view. Indeed, it was only temporarily magnified to 2,000-times its true brightness. Usually it is 'only' magnified by 600-times.

The team was able to rule out the source of light as being the supernova they were monitoring. "The source isn't getting hotter; it's not exploding. The light is just being magnified," said Kelly. "And that's what you expect from gravitational lensing." Kelly has also used Icarus to test a theory of dark matter and to investigate the composition of a foreground galaxy cluster. A statement says the team probed what is floating around in the foreground cluster and appeared to rule out the theory that dark matter is made up mostly of a large number of primordial black holes formed in the birth of the universe. If that was the case, they say, then light fluctuations from the background star would have looked different.

Kelly also says that more stars like Icarus are expected to be found when the more sensitive James Webb Space Telescope is launched. The joint collaboration between NASA, ESA and the Canadian Space Agency is set to be launched in May 2020.

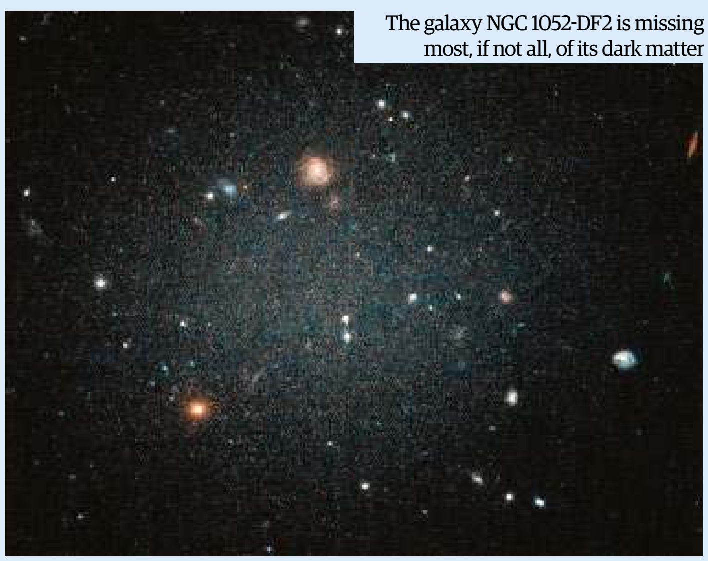
Dark-matter 'deficient' galaxy found

The finding has prompted scientists to reconsider how galaxies form

Astronomers are scratching their heads after a research team discovered a galaxy that seems to be devoid of any dark matter. Located millions of light years away, galaxy NGC-1052-DF2 appears to consist entirely of ordinary matter which, if proven, goes against the theory that dark matter should be present wherever ordinary matter exists.

Most astronomers subscribe to the notion that roughly 27 per cent of the universe is made up of dark matter, while ordinary matter - the stuff we can see - accounts for five per cent. The discovery - or non-discovery, if you like - that there is 400-times less dark matter than expected given the size of the galaxy raises the possibility it is a separate material elsewhere in the universe. It defies the idea that the interaction of stars and galaxies within dark matter produced the galaxies we see today.

"We thought that every galaxy had dark matter and that dark matter is how a galaxy begins," explains Pieter van Dokkum, Yale's Sol Goldman Family Professor of Astronomy. "So finding a galaxy without it is unexpected. It challenges the standard ideas of how we think galaxies work, and it shows that dark matter is real. It has its own separate existence apart from other components of galaxies. This result also suggests that there may be more than one way to form a galaxy."


The galaxy NGC 1052-DF2 is missing most, if not all, of its dark matter

Black holes could erase our past

Surviving certain black holes could lead to a future of infinite possibilities, says mathematician

Dr Hintz believes humans could pass the Cauchy horizon of a black hole and survive

Although physicists insist that very little can escape a black hole, an American mathematician is not only claiming that humans could survive, but that it would potentially lead them to have an infinite number of future possibilities.

In an intriguing paper, Peter Hintz, a postdoctoral fellow at the University of California, Berkeley, says venturing into relatively benign black holes would erase your past. And, since what has gone before shapes what's about to come, that would leave the years ahead completely wide open, with every outcome existing at once.

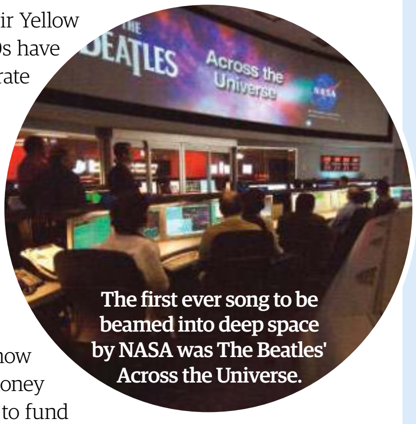
It goes against the idea of determinism where the physical laws of the universe only allow for one possible path. This is the basis upon which physics can be used to predict things, but Hintz is suggesting another side of the universe that is not governed by the rules of cause and effect and that it is possible – albeit not entirely feasible in a practical sense – that we could survive the passage from a deterministic world into a non-deterministic black hole. This doesn't mean Einstein's equations of general relativity are wrong, however.

"No physicist is going to travel into a black hole and measure it. This is a math question. But from that point of view, this makes Einstein's equations mathematically more interesting," he said. "This can really only be studied mathematically, but it has physical, almost philosophical implications, which makes it very cool."

And the beat goes on... Beatles' influence on the universe

An event during a week of celebration of all things space highlights the contribution of Britain's most successful band

The Beatles may be more famous for their Yellow Submarine, but the pop stars of the 1960s have also had an influence on space. To celebrate their contributions, a special event was held during the European Week of Astronomy and Space Science where it was shown just how Liverpool's most famous band can bring the study of celestial objects and the exploration of the universe closer to a large audience.



The first ever song to be beamed into deep space by NASA was The Beatles' Across the Universe.

The presentation drew on Viviana Ambrosi's book, *La Scienza dei Beatles* (The Science of the Beatles), explaining how the band's record company, EMI, used money from the sale of the iconic White Album to fund scientific research. This, Ambrosi points out, went towards Godfrey Hounsfield's research into X-rays, which led to the invention of the CT scanner.

The Beatles have also been to space – or at least their voices have. The 1969 release *Across the Universe* was transmitted by NASA in the direction of the star Polaris, 431 light years from Earth in 2008 using a 70-metre antenna in the Madrid Deep Space Communication Complex. Numerous songs, including a live wake-up call by Paul McCartney in 2005, have also been played on the International Space Station.

But that's not all. There are five asteroids named Beatles, Lennon, McCartney, Harrison and Starr, a crater on Mercury called Lennon and a white dwarf covered in crystalised carbon nicknamed Lucy, after the 1967 hit *Lucy In The Sky With Diamonds*. NASA has also named its first mission to Jupiter's Trojan asteroids Lucy. It is set to launch in 2021.

Space-time ripples forged in the heart of our Milky Way

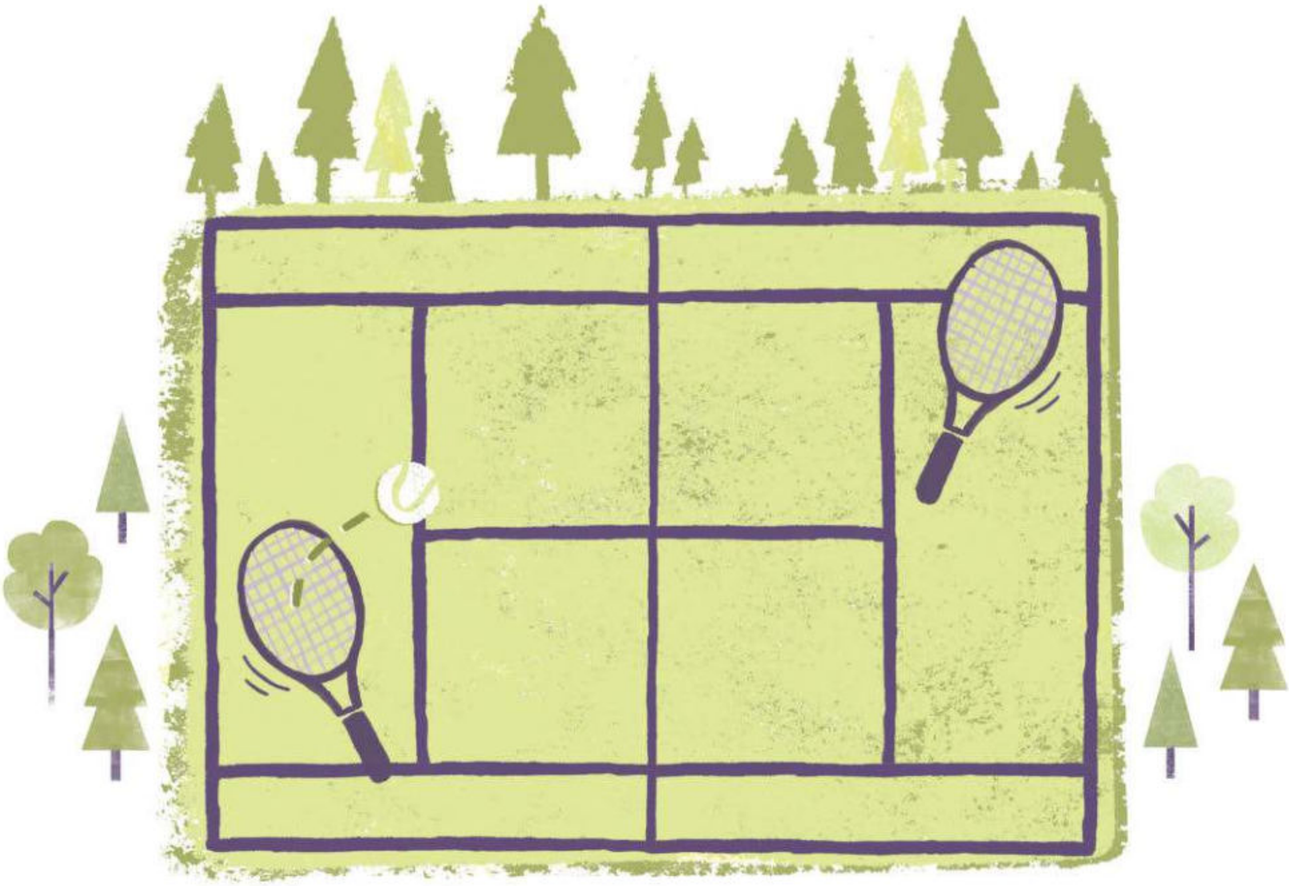
Giant black holes may be having a previously unknown influence on other black holes and gravitational waves

A new study suggests gravitational waves are created by black holes in the centre of most galaxies. According to Joseph Fernandez, a PhD student at Liverpool John Moores University, massive black holes can change the orbits of binary black holes – that is, those which orbit around each other in pairs.

When this happens, the black hole binary systems become tight and eccentric, forcing them to merge much faster than they otherwise would. This, Fernandez theorises, leads to observable gravitational waves. It could also, a statement suggests, flip the binary system orbital plane, making the black holes orbit in the opposite direction to their initial conditions.

The study goes some way to explaining how black hole mergers form by pulling them into very close or very eccentric orbits in order to collapse in a way that makes gravitational waves (small ripples in space-time that spread throughout the universe) much more observable.

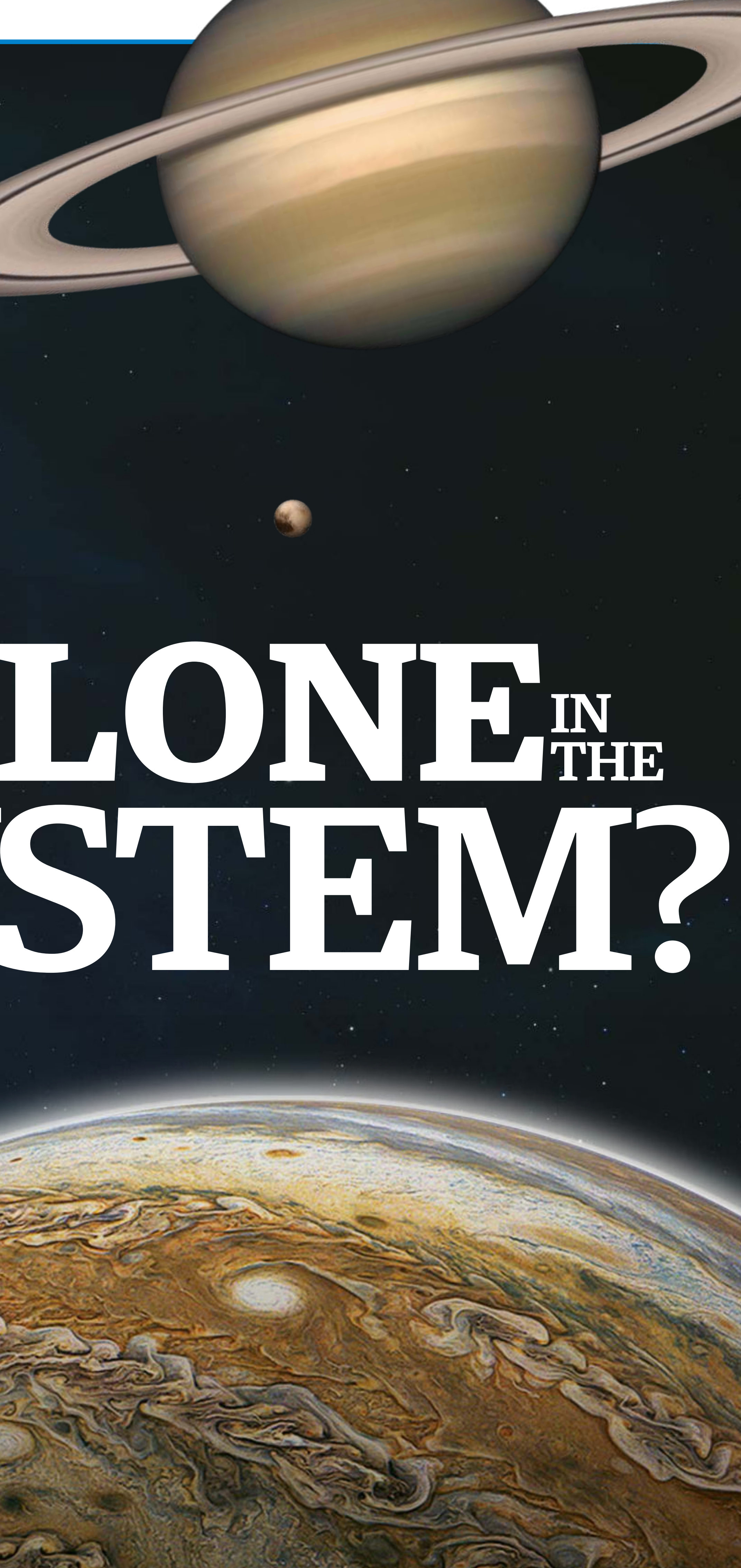
Sagittarius A* is the black hole at the centre of the Milky Way



ARE WE A
SOLAR SY

Astronomers and planetary scientists are racing to discover whether alien life is widespread among the worlds in our cosmic neighbourhood

Written by Giles Sparrow



LONE IN THE STEM?

It's not too long ago that scientists assumed our planet was the only place in the Solar System with the right conditions for life, but a series of stunning discoveries have recently shown that's far from the case. Instead of having to search for telltale hints in the light of distant planets orbiting other stars, perhaps alien life (at least in the most simplest form) is waiting to be found on our cosmic doorstep.

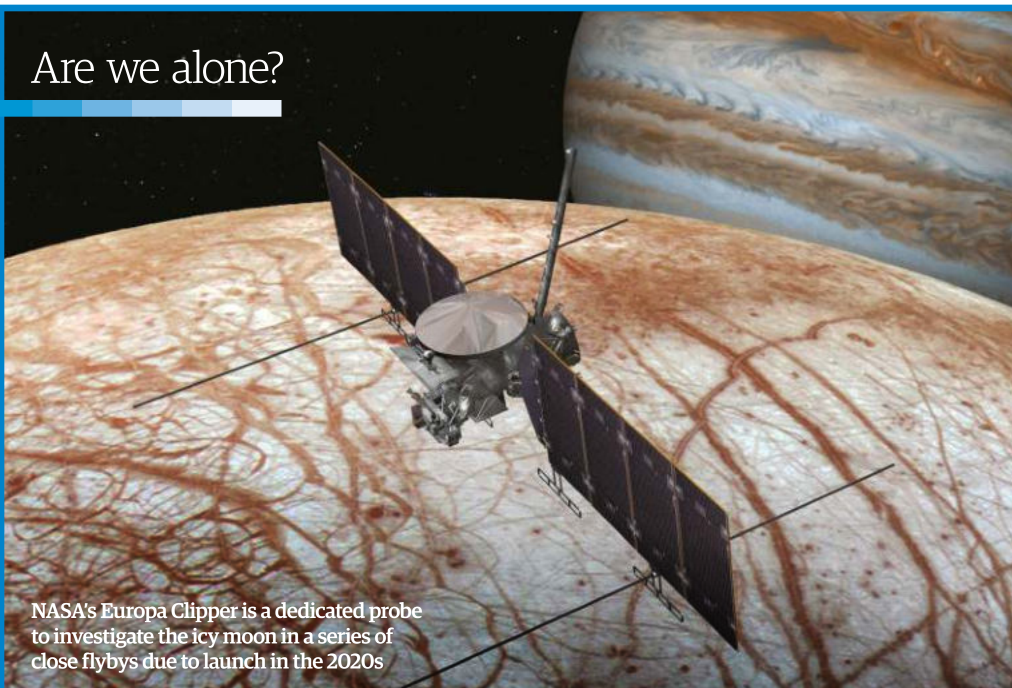
Ask a dozen biologists for a definition of life and you're likely to get a dozen different answers – life is one of those things that is hard to pin down, though you know it when you see it. Even the most open minded of biologists, however, tend to agree that two of the key requirements for life, which guide our chances of finding it elsewhere in the Solar System, are abundant carbon and a plentiful solvent, most likely liquid water.

Carbon is important because, of all the elements, it is the one best suited to building the hugely complex, self-replicating molecules required by most living processes. Fortunately it's one of the most common elements in our galaxy, generated in huge quantities by nuclear fusion processes inside stars and scattered through interstellar space when they die, for incorporation into later generations of stars and planets.

Water, meanwhile, is needed for the most basic of reasons: in order for the complex chemical precursors of life to arise, simpler chemicals must first encounter one another and go through chemical reactions. This means they must be able to move around, something that's most likely to happen when they're dissolved in a fluid solvent. The unique chemistry of water makes it the most effective solvent among all liquids that commonly occur in nature, and once again we're fortunate that it seems to be widespread in our galaxy.

So what can the requirement for these two basic ingredients tell us about the possibilities for life in our Solar System? While carbon is commonplace across all the Solar System's planets and moons, liquid water seems at first glance to be a much trickier requirement – Earth is the only planet with abundant surface water, thanks to its position in the Solar System's 'Goldilocks zone', where temperatures are neither so hot that the oceans boil away into the atmosphere, nor so cold that they freeze solid. Up until the dawn of the space age, many astronomers suspected that our neighbouring planets, Venus and Mars, might also have liquid water on their surfaces, but the first spaceprobe flybys put an end to these hopes, revealing Venus as a toxic, roasting hellhole and Mars as a frozen, arid desert.

Fortunately it's now clear that the Goldilocks zone isn't the be-all and end-all of possibilities for life. Planetary scientists have discovered evidence



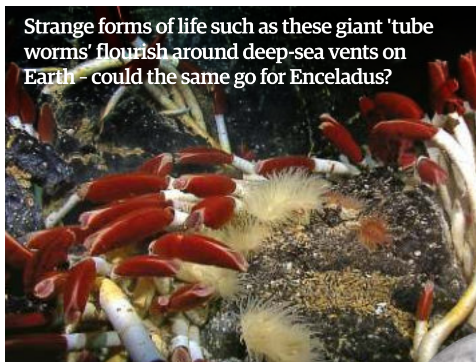
NASA's Europa Clipper is a dedicated probe to investigate the icy moon in a series of close flybys due to launch in the 2020s

for liquid water in surprising places across the Solar System – for example hidden beneath the icy crusts of moons whose interiors are heated by the strong tidal forces of their parent planets, or perhaps kept liquid even at sub-zero temperatures by the presence of other chemicals such as salts or ammonia. Meanwhile, in the past few decades, biologists have also found that life on Earth is able to thrive in extremes of acid, alkali, heat, cold and darkness very different from those we normally experience. The discovery of these 'extremophile' organisms has opened up a whole range of new habitats where life might exist beyond Earth.

When it comes to the basic materials for life in the Solar System, it now seems that all bets are off – so where should we look, and what might we find?

At first glance, Mars remains the most obvious candidate as an environment for life. Since those early disappointments, photographs and other data from orbiting spaceprobes, along with soil analysis by surface rovers, have revealed there's much more to the Red Planet than arid desert. The surface soil is mixed with large amounts of ice to form permafrost, and in some places even flows to create glacier-like features. Ancient features also show that liquid water flowed freely on the surface

Electron microscopy of Martian asteroid ALH84001 revealed tiny microbe-like 'fossils' whose true nature is still controversial



Strange forms of life such as these giant 'tube worms' flourish around deep-sea vents on Earth – could the same go for Enceladus?

in the distant past, when the Martian atmosphere was thicker and its orbit was perhaps different. Mars almost certainly had the right conditions for life to gain a foothold billions of years ago – but is there any chance it could still cling on today?

So far the only experiments to deliberately search for life on the Martian surface were carried aboard the Viking missions of the 1970s. These robot landers exposed soil samples to a series of chemical reactions and looked for signs of living metabolic processes. They produced inconclusive results and have never been properly repeated – the British-built Beagle 2 Lander, designed to continue the direct search for life, sadly ended up wrecked on the Martian surface during its 2003 landing.

Perhaps the most controversial evidence for life, however, comes from a meteorite called ALH84001 – a fragment of 4.5-billion-year-old Martian rock that was blasted off the planet in a meteorite impact and fell to Earth in Antarctica about 13,000 years ago. In 1996, a team of NASA scientists claimed to have discovered chemical biomarkers (molecules created by biological activity) and microscopic fossil-like structures within it. They suspected the action of primitive 'nanobacteria', similar to (though much

"Discovery of these 'extremophile' organisms has opened up a whole range of new habitats where life might exist"

Ocean worlds

How do the worlds of the outer Solar System measure up to Earth in terms of water content?

Total amount of water/ice compared to Earth

Ganymede x39.5

The largest moon in the Solar System, Ganymede has a high water content. In the past, floating plates of ice rearranged themselves on a global water ocean, and a remnant of this ocean remains liquid today.

Triton x4.9

Neptune's largest moon Triton is thought to be a captured dwarf planet from the outer edge of the Solar System with a similar proportion of ice to Pluto, and potential for its own hidden oceans.

Callisto x17.8

The outermost Galilean satellite of Jupiter, Callisto is huge and contains large quantities of ice. Scientists still aren't entirely sure what caused some of it to melt into a liquid ocean.

Titan
x20.6

Titan's hydrocarbon-rich surface covers an ice-rich world that probably has a buried liquid-water layer, giving this giant moon potential for two entirely independent ecosystems.

Europa
x2.1

Slightly smaller than Earth's Moon, Europa actually contains a relatively large proportion of rock compared to ice.

Enceladus
3.2%

Enceladus is made almost entirely of water ice, but with a diameter of a mere 504km (313 miles), it only has a small fraction of Earth's overall water content.

Pluto
x3.1

The distant dwarf planet Pluto is made almost entirely of ice. A liquid ocean layer is probably warmed by tidal forces from its giant moon Charon.

Dione
34%

Saturn's mid-sized moon Dione is larger and contains more ice than Enceladus. It probably has a hidden ocean, but in Dione's case this is buried more than 100km (62 miles) below the surface.

Earth
1.4*

More than 70 per cent of Earth's surface is covered in water, but Earth's oceans form a relatively shallow layer compared to those on some other Solar System worlds.

*1.4 billion km^3

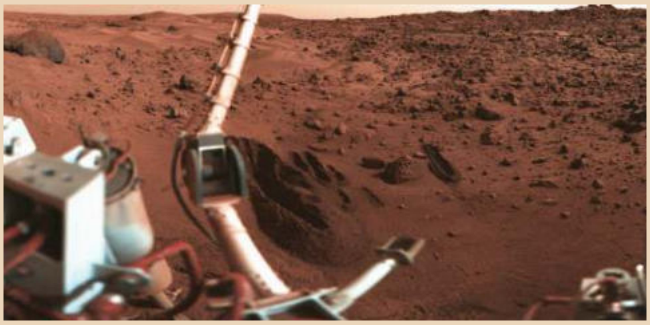
Hunt for life in the Solar System

Much of the new evidence for habitable environments in our solar neighbourhood has come from visiting space probes

Viking landers

Target: Mars

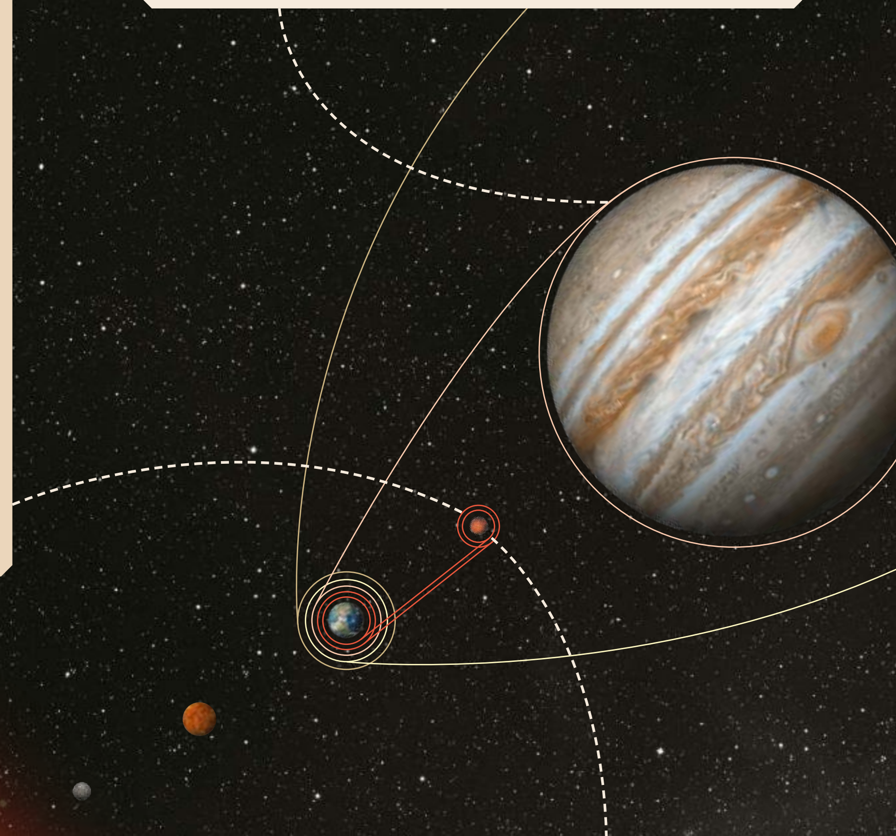
The Viking landers carried a 'Labelled Release' experiment that 'fed' samples of Martian soil with nutrients that were tagged with a radioactive carbon isotope. The rocks subsequently released radioactive CO_2 gas, possibly indicating that microbes in the soil had processed the nutrients. However, attempts to repeat the test were met with negative results, so the case for life is not proven. Later probes discovered potentially toxic perchlorate chemicals on the Martian surface, so any Martian life might only survive below ground.



Galileo

Target: Europa, Ganymede and Callisto

NASA's Galileo orbiter spent almost eight years in orbit around the giant planet Jupiter and studied each of its giant moons. Galileo's magnetometer instrument detected changes to Jupiter's magnetic field around Europa, Ganymede and Callisto, which indicate the presence of saltwater oceans on each. The probe also captured detailed photographs of Europa that point to a crust of shifting ice rafts above an ocean warmed by hydrothermal vents.

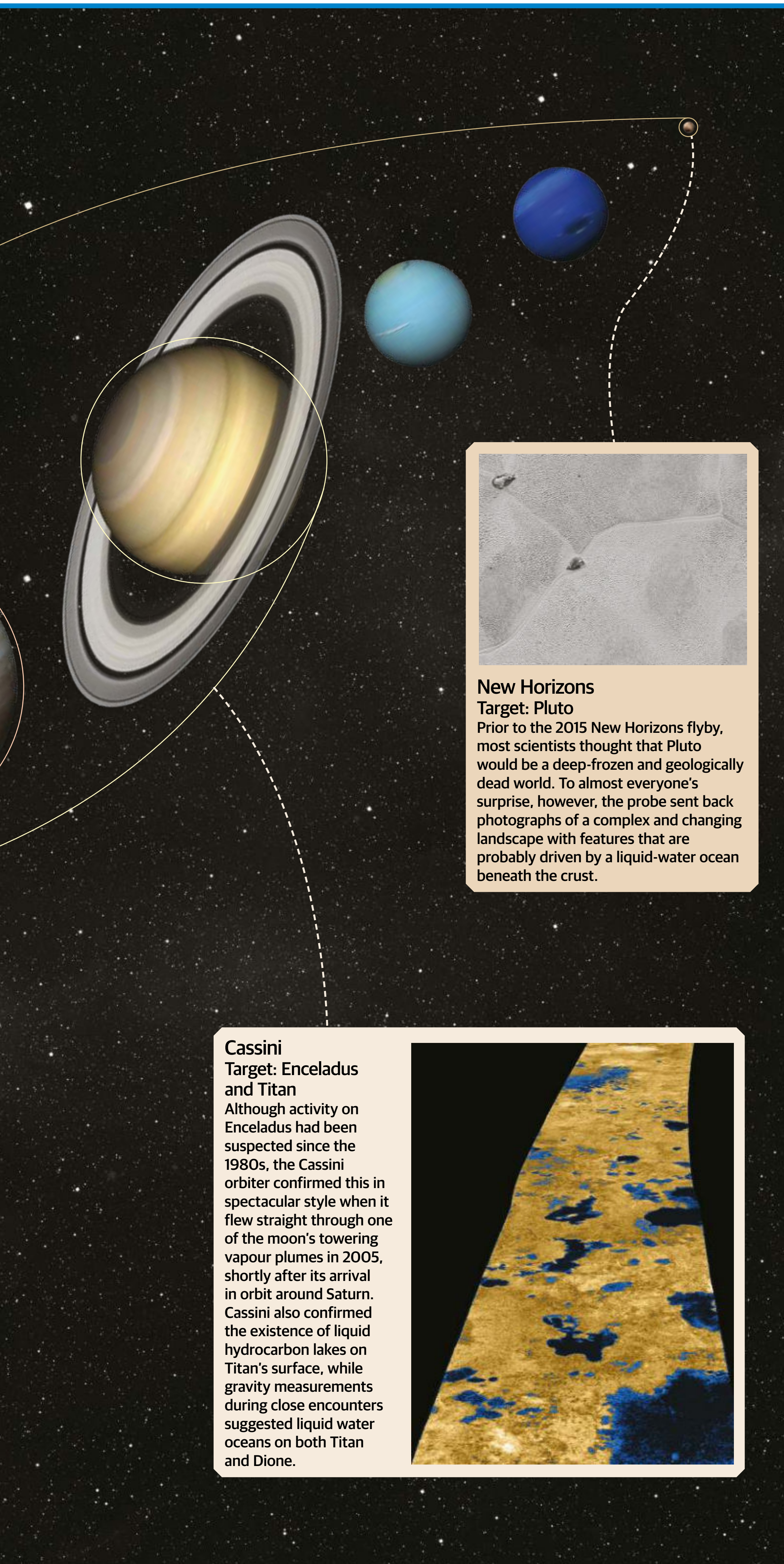


Curiosity

Target: Mars

NASA's Curiosity rover carries a Tunable Laser Spectrometer instrument that can sniff out tiny traces of atmospheric gas down to a part per billion or less. When it arrived, scientists were disappointed to find no signs of the methane detected in Earth-based measurements, but Curiosity has since detected methane 'spikes' that seem to be linked to the seasons, and these could be the strongest evidence for life so far.

> "Mars almost certainly had the right conditions for life to gain a foothold billions of years ago"



New Horizons
Target: Pluto
Prior to the 2015 New Horizons flyby, most scientists thought that Pluto would be a deep-frozen and geologically dead world. To almost everyone's surprise, however, the probe sent back photographs of a complex and changing landscape with features that are probably driven by a liquid-water ocean beneath the crust.

Cassini
Target: Enceladus and Titan
Although activity on Enceladus had been suspected since the 1980s, the Cassini orbiter confirmed this in spectacular style when it flew straight through one of the moon's towering vapour plumes in 2005, shortly after its arrival in orbit around Saturn. Cassini also confirmed the existence of liquid hydrocarbon lakes on Titan's surface, while gravity measurements during close encounters suggested liquid water oceans on both Titan and Dione.

The panspermia theory suggests that comets have seeded many of our Solar System's worlds with life

smaller than) some of Earth's own 'extremophile' bacteria. The claim remains hugely controversial, however – other scientists have proposed ways for the molecules and 'fossils' to have arisen without the need for life, and the matter probably won't be settled for good until scientists have more samples of Martian rock to examine.

But is today's Mars suitable for life? Conclusive evidence of liquid water on the surface today (perhaps seeping from underground water tables) remains frustratingly elusive, and while a lack of liquid water on Mars today wouldn't entirely rule out specially adapted microbes, it would seem to make it far less likely.

Balanced against this, the most intriguing evidence for possible Martian life so far comes from the detection of methane gas. The first traces of methane (a few parts per billion in the atmosphere) were discovered from Earth-based telescopes and orbiting spaceprobes in the early 2000s, and have since been confirmed by rovers such as NASA's Curiosity. The gas is puzzling because it is unstable in Martian conditions – fierce ultraviolet radiation should rapidly break its molecules apart – so for methane to persist, something must be constantly producing it.

On Earth, methane is produced by living organisms or geological activity such as active volcanoes. Volcanism or other processes can't yet be ruled out, but the announcement in early 2018 of a seasonal cycle in which methane levels in the Martian northern hemisphere rise to a peak in later summer adds to the mystery – could it be that methane-producing microbes are stirred into activity by the summer sunshine? The European Space Agency's and Roscosmos' ExoMars Trace Gas Orbiter, due to start work in orbit around the Red Planet, may shed more light on the mystery.

Further out in the Solar System, a good handful of worlds offer tantalising prospects for life. Solid worlds beyond the middle of the asteroid belt – such as dwarf planets, moons, asteroids and comets – are made from rock and ice mixed in varying amounts, and it's now clear that tidal forces raised on satellites orbiting giant planets, or simply the addition of chemicals that lower the freezing point of water, can be enough to create a deep liquid ocean layer beneath a solid outer crust.

The best known examples of such hidden oceans are Jupiter's satellite Europa and Saturn's moon

Enceladus. On Europa, a 25-kilometre- (15-mile) thick outer crust of jostling ice plates slowly drifts and rearranges itself on top of a global ocean about 160-kilometres (100-miles) deep. The ocean on Enceladus is shallower, but closer to the surface, with the crust just five-kilometres (three-miles) thick in places. On Enceladus at least, sea-floor hydrothermal vents belch out gas and minerals from deep within the crust. The environment around these vents could provide an ideal oasis for life to arise (indeed, many biologists now suspect that life on Earth got started around similar vents).

Although it's currently impossible to investigate these hidden oceans directly, both moons release plumes of vapour into space which we can study. The jets above Enceladus have already provided clues to conditions in its ocean – molecules of hydrogen within them have been linked to active undersea vents. Europa's vapour plumes are thinner and more intermittent – they may not escape directly from the ocean, but might instead be knocked off the moon's icy surface by radiation from the Sun and Jupiter. But since Europa's surface ice is itself made up of solidified and recycled ocean ice, even this could offer important clues. NASA's Europa Clipper mission, planned to launch in the mid-2020s, will aim to find out more.

Together, Europa and Enceladus are probably the Solar System's most likely habitats for alien life – and perhaps not just single-celled microbes, but more advanced creatures that have evolved to suit their environment. Such organisms might have streamlined shapes similar to fish, or flexible forms that take advantage of buoyant conditions, like squid and other cephalopods. But then again, it's worth bearing in mind that single-celled life on Earth existed for at least 3 billion years before blossoming into varied, multicellular organisms (for reasons that we don't yet fully understand).

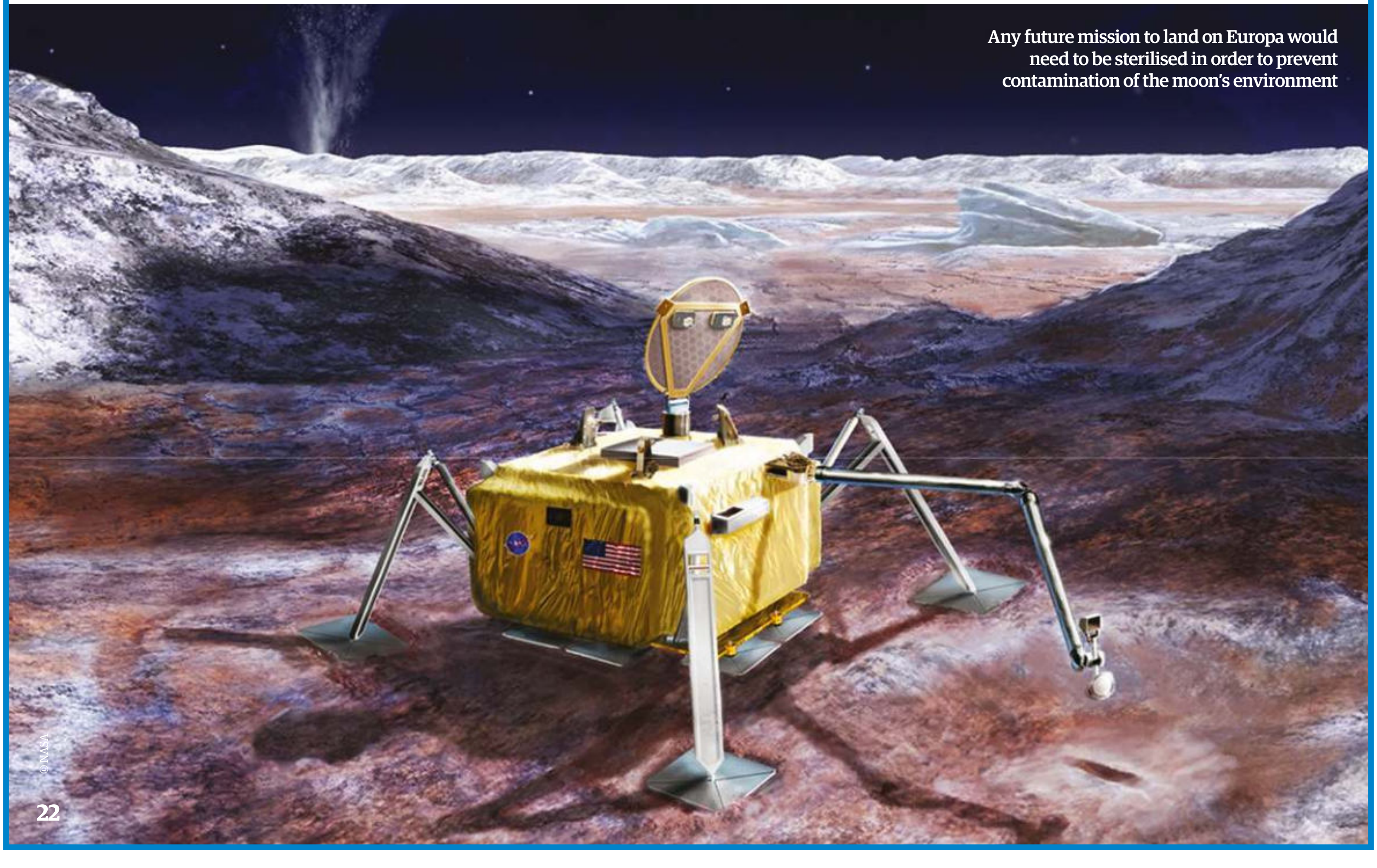
"Europa and Enceladus are probably the Solar System's most likely habitats for life – and not just single-celled microbes"

Aside from these two icy showcases, it's now clear that many other Solar System bodies could have hidden oceans deep beneath their surfaces. On Jupiter's giant moons Ganymede and Callisto, that water is sealed off hundreds of kilometres below the surface, and detectable only through interactions with Jupiter's magnetic field. NASA's Dawn asteroid probe has revealed signs of a hidden ocean on the largest asteroid, Ceres, and there could even be liquid water on distant Pluto. During its 2015 flyby, the New Horizons mission photographed extraordinary features that many believe could only have been created by the effects of a fluid mantle just beneath the crust. Any of these worlds could have their own hydrothermal vents, and potentially their own life, though it would be far harder for us to detect and investigate.

However, if there's a prize for the most unlikely potential outpost for life, it must surely go to Titan. Cloaked in an opaque, nitrogen-rich atmosphere, Saturn's largest moon is one of the coldest worlds in the Solar System, allowing hydrocarbons such as methane to condense into liquid and play a similar role to that of water on Earth. Methane rains from clouds, erodes a landscape covered in oily hydrocarbon ices and, amazingly, collects in lakes near the poles.

In many ways, Titan is a low-temperature version of Earth – so if it has its own surface liquid, could it also have its own life? There's carbon aplenty, and indeed hydrocarbon molecules are an important first step on the way towards complex biochemistry. But while liquid methane is a less efficient solvent than water, once chemicals are dissolved, they are more likely to persist and remain stable for longer, giving greater potential for life-giving reactions to arise.

Regardless of the form it takes, if life is found to be widespread across the Solar System, it could have huge implications for our understanding of the wider universe. If, for example, life on other worlds turned out to share basic biological features, it would support the so-called 'panspermia' theory that life is carried between worlds, and perhaps even between stars, on comets and meteorites. If different strains of life prove to be entirely independent, it would suggest that life arises naturally wherever conditions are even remotely suitable. In either case, we could expect basic life in our galaxy to be equally commonplace – perhaps even giving rise to intelligent aliens that we might one day contact.



Any future mission to land on Europa would need to be sterilised in order to prevent contamination of the moon's environment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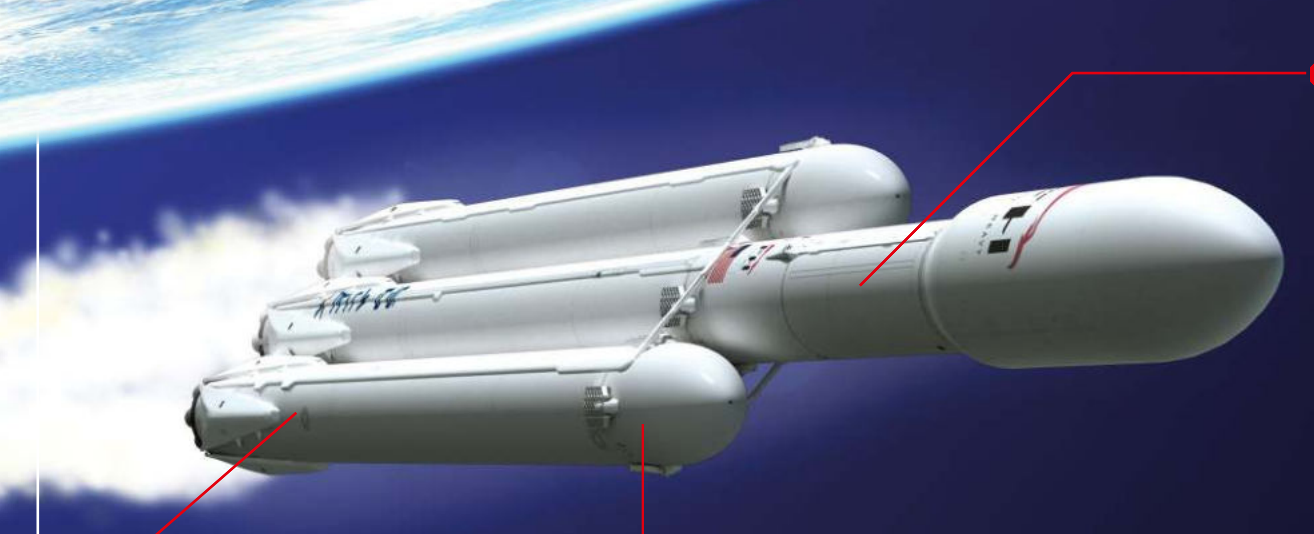


Moon mission to go!

The proliferation of new launch vehicles, habitats and landers under development means it'll soon be possible to build your own lunar spacecraft to order

When President Kennedy declared in 1961 that the US would reach the Moon before the end of the decade, it thrust NASA into uncharted territory. Only two humans had travelled into space, flying on adapted missiles, for some 108 and 15.5 minutes. No spacecraft had ever docked in space, no human had left Earth orbit and nothing at all had made a soft landing on another celestial body. Every part of the mission had to be designed, developed and, in many cases, invented from scratch. It's difficult to appreciate now how bold the plan really was.

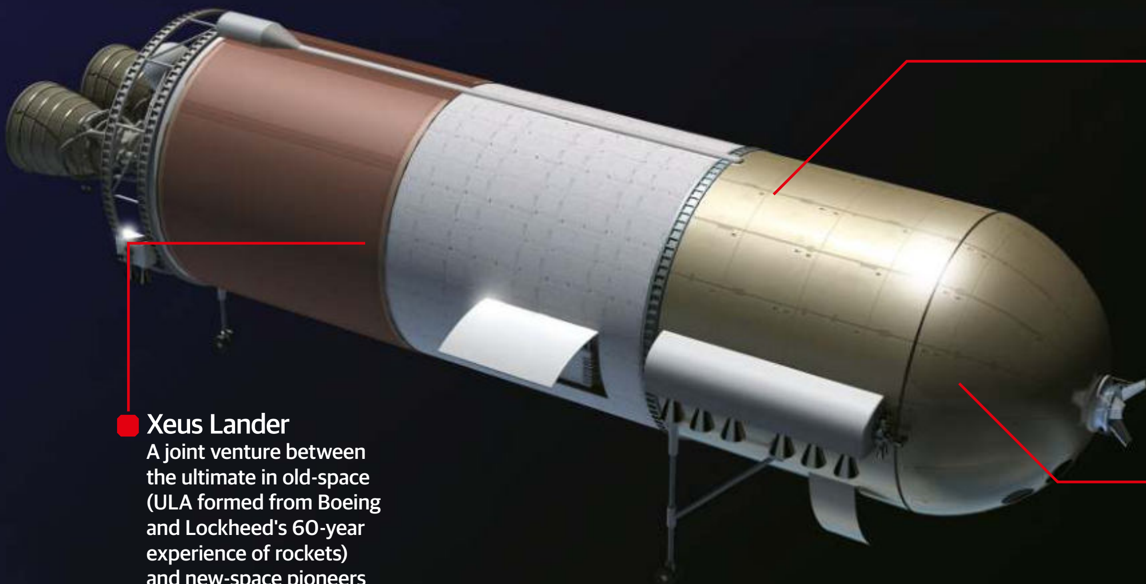
With the end of the Apollo program, the Space Shuttle was supposed to make launch cheap, easy, frequent and safe, but failed on all four counts. Commercial satellite launch became a successful, but very expensive business and robotic Solar System exploration has accomplished amazing results, but no humans have left Earth's orbit since Apollo 17 in 1972. However, since the turn of the century the space industry has been revolutionised: SpaceX has forced space launch to move forward by dramatically cutting launch costs, and along with Boeing they are on the verge of launching their own personnel transport pods for NASA. Boeing is also cooperating with Bigelow Aerospace who are developing huge pre-packed inflatable space stations, and recently had a module attached to the International Space Station. This explosion of projects, in particular mostly reusable heavy-lift rockets like SpaceX's Falcon Heavy and Blue Origin's New Glenn, moves us into fascinating territory; it is becoming possible for a country, a company or even just a rich individual to build a Moon mission out of the existing products of a number of companies.

Dr Doug Plata, a physician and space advocate, has established the Space Development Network to promote a sustainable lunar transportation project based upon this new surge in technology. He has proposed a near-term mission based on the Falcon Heavy and the United Launch Alliance's (ULA) Xeus lander, though other rockets could be used as they become available.

In Plata's proposal a robotic propellant production plant would manufacture oxygen and hydrogen supplies from lunar ice reserves. Once this fuel depot is established Falcon Heavys could pitch 20 tonnes directly towards the Moon, which would be exchanged with a Moon-refuelled lunar lander halfway there, and there is an innovative lander almost, comparatively, ready to go.

The Xeus lander is a concept created by ULA in cooperation with new-space company Masten Space Systems. It proposes to use ULA's Centaur, a high-energy, upper rocket stage powered by

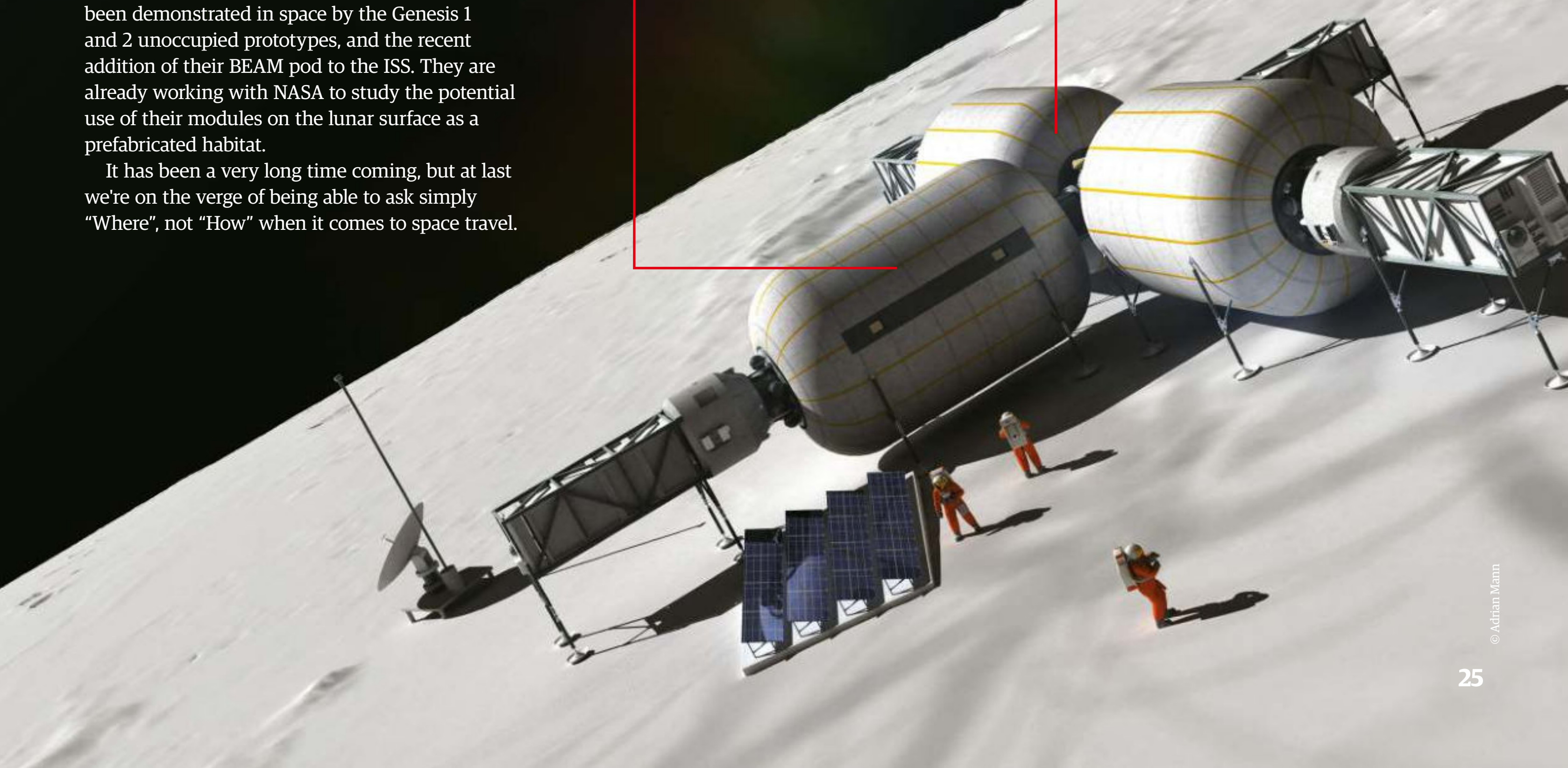
> "It is becoming possible for a country, a company or even just a rich individual to build a Moon mission"

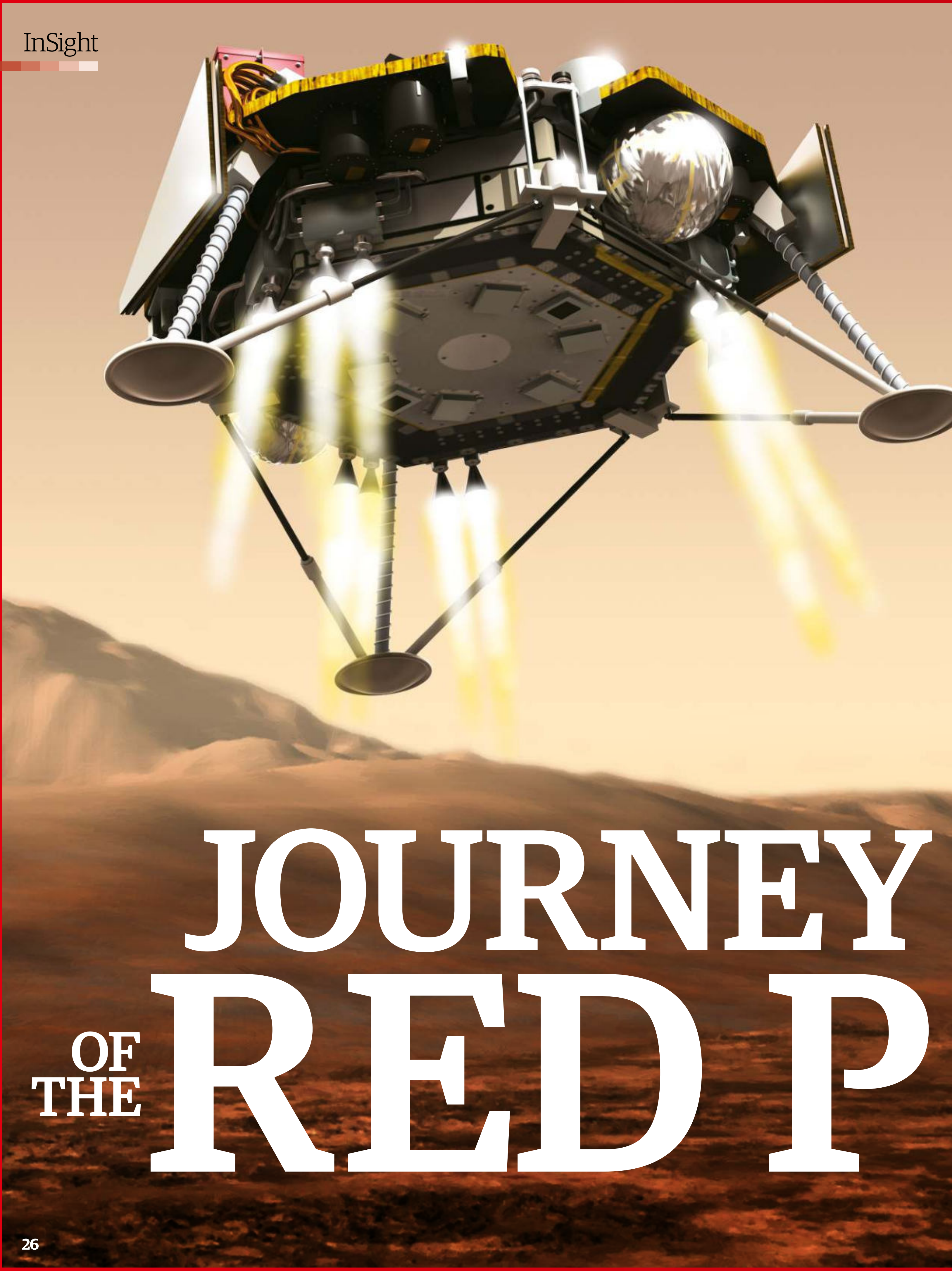


liquid oxygen and liquid hydrogen, and its earliest version was first launched in 1962. Over its 56-year career it has propelled the Viking Martian orbiters and landers, both Voyagers and Cassini on interplanetary missions. ULA hope to be able to build upon the reliability of the stage, combined with Masten's vertical landing expertise, to create a relatively inexpensive lunar lander capable of delivering up to 10 tonnes to the lunar surface. But getting to the Moon is one thing, what do we do about accommodation when we get there?

Well this is where Bigelow Aerospace can nearly pull something off the shelf already. At the turn of the century Bigelow licensed a cancelled NASA concept for inflatable (they prefer to call them expandable) space stations. They have been developing the technology ever since in anticipation of a space launch revolution. It has been demonstrated in space by the Genesis 1 and 2 unoccupied prototypes, and the recent addition of their BEAM pod to the ISS. They are already working with NASA to study the potential use of their modules on the lunar surface as a prefabricated habitat.

It has been a very long time coming, but at last we're on the verge of being able to ask simply “Where”, not “How” when it comes to space travel.





JOURNEY OF THE RED P

TO THE CENTRE
LANET

Meet the lander to peel off the face of Mars and tell us what is really going on underneath its surface

Reported by Lee Cavendish

Mars is the second-most studied planet - only behind our own - but we know virtually nothing about its interior. All astronomers have to go by is models and theories, but no concrete evidence. NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, or 'InSight', mission will look beneath the surface of Mars to reveal the secrets within the Red Planet. With its launch just on the horizon, scientists around the world eagerly anticipate the arrival of the lander that will reveal the intricacies of our neighbouring planet.

About 4.5 billion years ago, the eight planets of our Solar System were formed. All eight planets were formed from a clumpy disc of rock, ice and debris orbiting the young Sun. Fast-forward to the present and we now see a distinct difference between the inner and outer planets. The terrestrial planets (Mercury, Venus, Earth and Mars) all have a dense, rocky structure, with only one able to support life. The Jovian planets (Jupiter, Saturn, Uranus and Neptune) are all primarily gas and swollen up to enormous sizes. The question that astronomers still can't answer, though, is how did these terrestrial planets form and evolve?

Thanks to modern technology and perseverance, astronomers have tried to answer this question in a period of extensive exploration of one of our closest neighbours, Mars. However, previous missions have only been able to scratch the surface. Where landers, rovers and orbiters before it have been in the hot pursuit of water on the dry, sandy surface, or designed to study the planet's tiny atmosphere, InSight is delving deeper into the unknown. By putting an ear to the ground, astronomers will get a more comprehensive understanding of the Red Planet's core, mantle and crust.

"The objectives of the mission are to map the structure and thermal state of the deep interior of Mars for the first time, and to use this information to better understand the early formation processes of terrestrial planets, including the Earth," Dr Bruce Banerdt, principal investigator of the InSight mission, tells **All About Space**.

Dr Bruce Banerdt is the principal investigator of the InSight mission

Originally due to launch in March 2016, InSight suffered a major setback when a vacuum leak was found in one of the lander's key instruments in December 2015. Now the time is finally here. On 5 May 2018, InSight is scheduled to launch from the Vandenberg Air Force Base in California, United States on board an Atlas V-401 rocket. This will be the first interplanetary mission to take off from the United States' West Coast.

After its launch, the InSight payload and its first two CubeSats, which will provide a more efficient data relay back to Earth, will endure a six-month (or so) journey before their arrival at a planet redder, drier and roughly half the size of Earth. From here, InSight can finally join its NASA predecessors as it finds unequivocally important and revolutionary results. When NASA sent their first successful orbiter in 1971, the Mariner 9, it became the first spacecraft to orbit another planet, sending back over 7,300 images of the Martian surface and its two moons. Since then, humans have maintained an impressive number of satellites in orbit and probes on the surface, including the late and great missions such as the Mars Global Surveyor orbiter, the Viking 1 and 2 missions and the Spirit rover. There are also many functioning visitors still at Mars, including the Curiosity and Opportunity rovers and the Mars Reconnaissance Orbiter (MRO) and Mars Atmosphere and Volatile Evolution Mission (MAVEN).

The Phoenix lander, which was launched on 4 August 2007 and laid stationary on the surface for 157 Martian days (also known as a sol, which is roughly 40 minutes longer than an Earth day), is the mission that InSight's design is based on. "InSight will use the same lander design as the 2007 Phoenix mission, which gives us a proven landing and surface system without the cost of developing them from scratch," Banerdt explains. "Plus, we will be using several orbiters at Mars to relay back to Earth our precious data. It's hard to overstate the extent that knowledge from earlier missions informs InSight science."

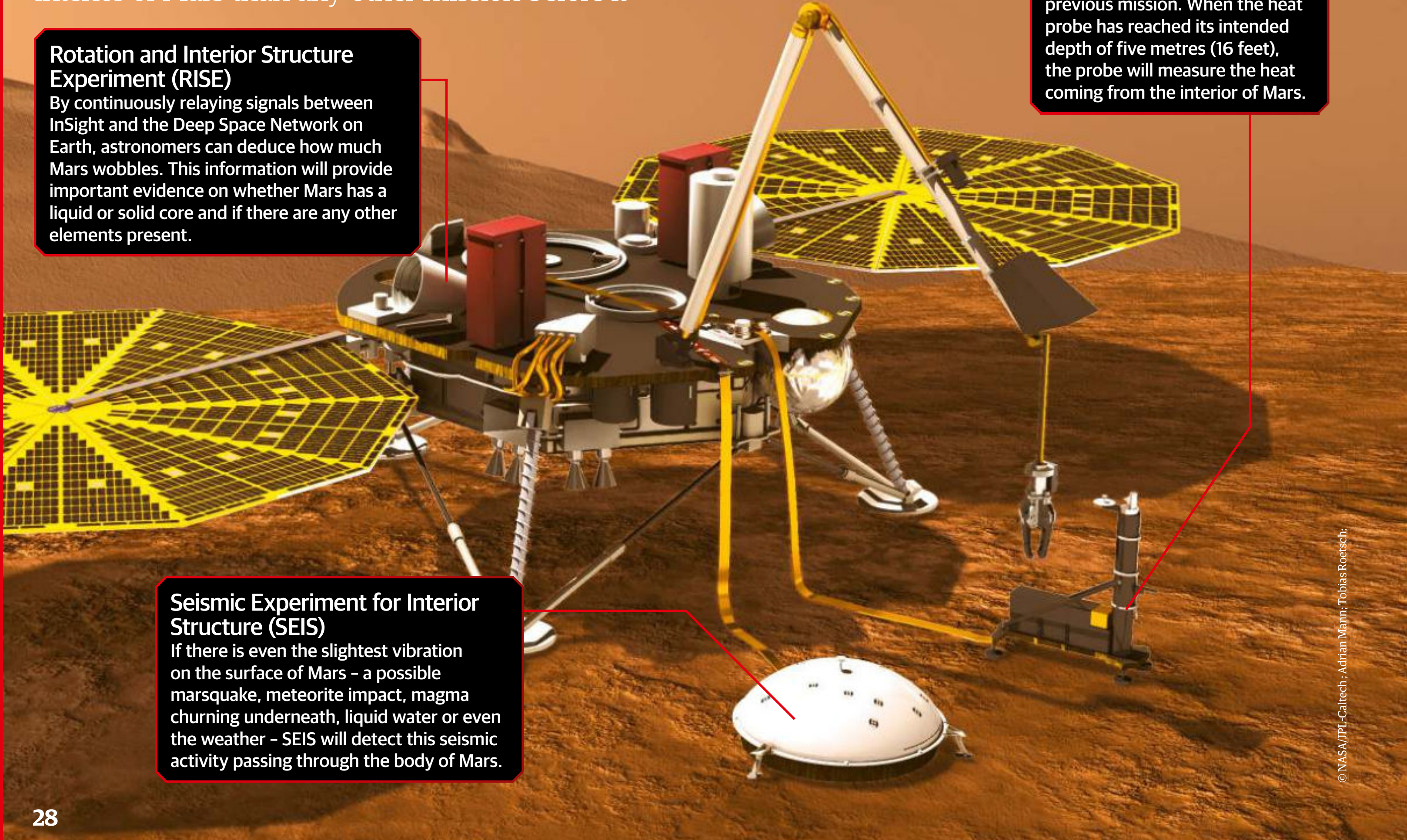
The InSight lander will stand at a height between 83 to 108 centimetres (33 to 43 inches) above the Martian surface, and once InSight's solar panels are deployed, its total span will be six metres (19.7 feet). This is roughly equivalent to two-thirds of the length of a London bus. Overall the whole lander will weigh 360 kilograms (794 pounds), which is about 88 per cent of the mass of the Phoenix lander. Packed within this bundle are some of the finest and most sensitive instruments to ever grace the planet's soil, and they are required to function for at least one Martian year, which is roughly equivalent to two Earth years.

Before these instruments can blossom, the InSight rover needs to survive what is commonly referred to as the 'seven minutes of terror'. In these seven minutes, the lander has to go from travelling at 22,692 kilometres (14,100 miles) per hour through the atmosphere of Mars, to a dead stop on the surface. As Mars' atmosphere is 100 times thinner than Earth's, slowing down the spacecraft is a much more difficult task. To succeed, a heat shield will cause as much friction with as little atmosphere as possible, causing the shield to reach extreme temperatures. The spacecraft will then deploy its

"The objectives are to map the structure and thermal state of the deep interior of Mars for the first time" **Dr Bruce Banerdt**

InSight's instrumental trifecta

These three instruments will tell us more about the interior of Mars than any other mission before it



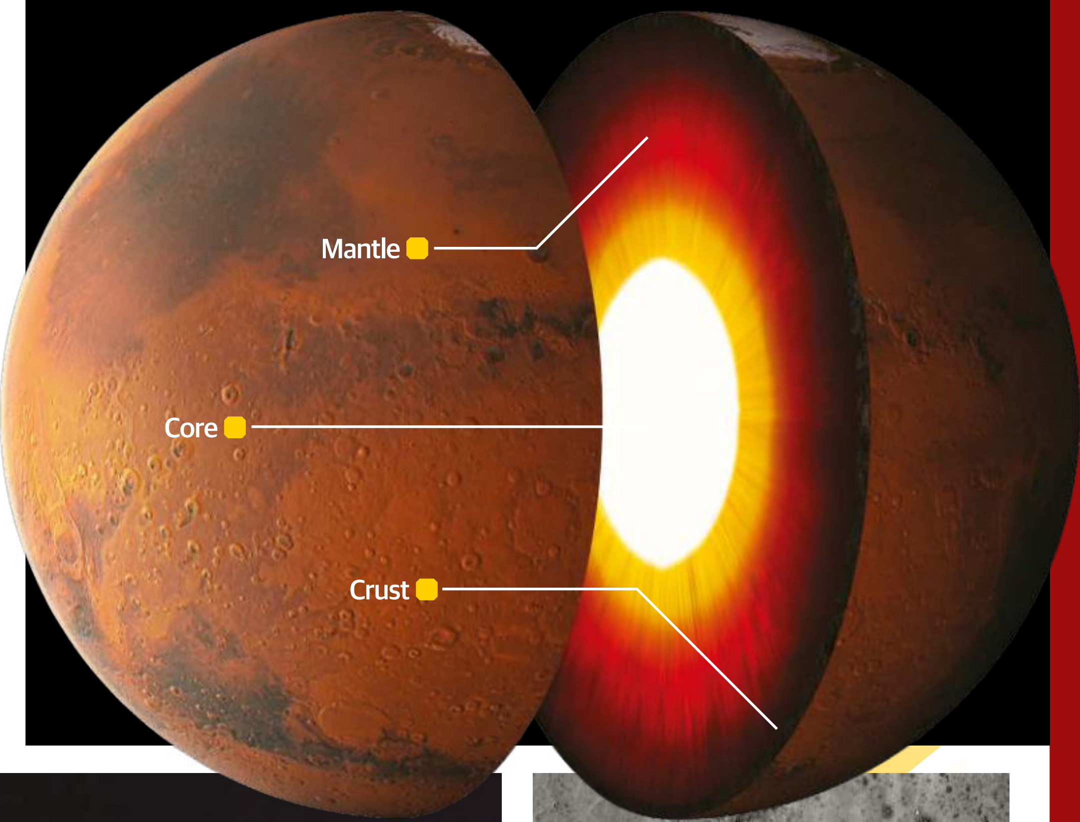
parachute, jettison its heat shield and extend its legs. After bringing the lander to a reasonable descending speed, the parachute is shed and 12 boosters at the bottom of the lander begin firing. This provides the final cushion before it lands in Elysium Planitia.

When asked about why Elysium Planitia was selected as the designated home for the duration of InSight's mission, Dr Matthew Golombek, InSight's landing site lead, told **All About Space** it's because "it meets all the engineering constraints for landing and surviving for a Mars year. It is low in elevation, near the equator and smooth, flat and relatively rock free over the landing ellipse."

Once landing is complete and InSight has reached its destination, its solar panels and instruments can be prepared. The blooming of the solar panels is the most essential part of the whole mission, as the lander will be powered by the less intense rays of a further away Sun. The Sun shines roughly half as bright on Mars than Earth, meaning InSight's solar panels need to be able to squeeze as much solar juice out of those rays as possible.

Once its solar wings are spread the instruments can be deployed, and the mysteries of Mars' mischievous mantle and core can be unveiled. The Instrument Deployment Arm (IDA) will place the seismometer, the Seismic Experiment for Interior Structure (SEIS) and the heat flow probe, the Heat Flow and Physical Properties Probe (HP³), on the

Inside Mars




The 'cruise' configuration endured much testing ahead of its six-month journey from Earth to Mars


Elysium Planitia was chosen as the most ideal landing site for InSight

NASA at Mars

The space agency has steadily developed an impressive entourage either orbiting or roaming the Martian surface

Mars Global Surveyor

This satellite spent over nine years imaging and mapping the entire globe's atmosphere and surface before NASA lost contact with it on 2 November 2006.

Mariner 9

Launched on 30 May 1971, Mariner 9 became the first spacecraft to orbit another planet. It mapped 85 per cent of the Martian surface and also collected valuable atmospheric information.

Phoenix

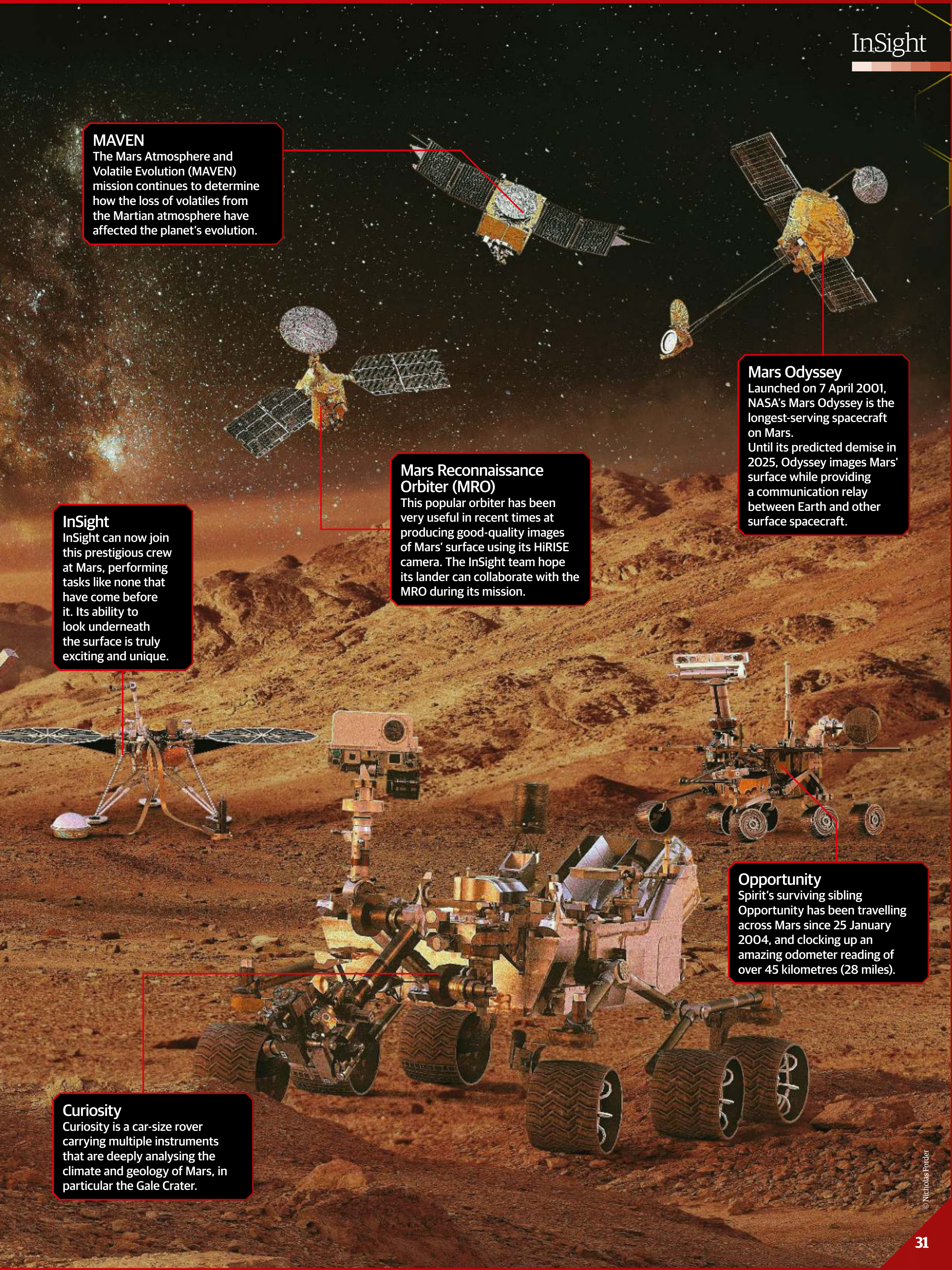
The lander of which InSight uses the same design, Phoenix landed on Mars on 25 May 2008 and lasted 157 sols. It included an array of instruments conducting different tasks on the surface of Mars.

Viking program

In 1975, NASA launched two sets of orbiters and landers known as Viking 1 & 2. The landers would study the planet from the surface while the orbiter imaged it from above.

Spirit

The fallen sibling of Opportunity, this rover spent 2,210 sols in operation, searching for evidence of water on Mars before getting stuck and falling silent.



MAVEN
The Mars Atmosphere and Volatile Evolution (MAVEN) mission continues to determine how the loss of volatiles from the Martian atmosphere have affected the planet's evolution.

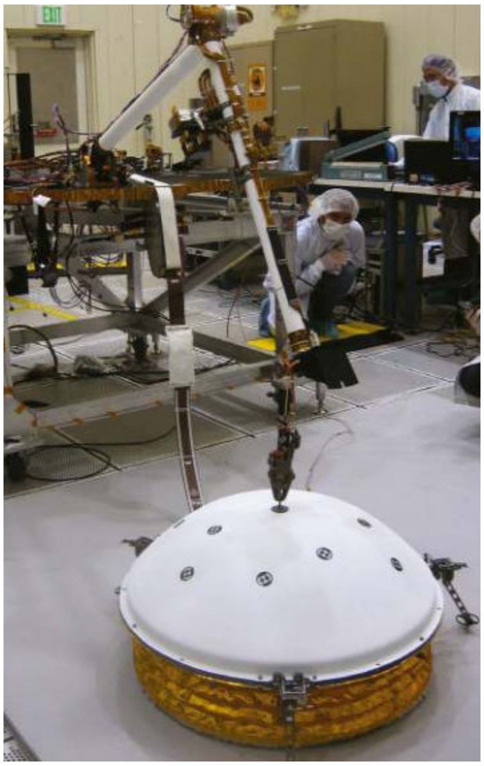
Mars Odyssey
Launched on 7 April 2001, NASA's Mars Odyssey is the longest-serving spacecraft on Mars.
Until its predicted demise in 2025, Odyssey images Mars' surface while providing a communication relay between Earth and other surface spacecraft.

Mars Reconnaissance Orbiter (MRO)
This popular orbiter has been very useful in recent times at producing good-quality images of Mars' surface using its HiRISE camera. The InSight team hope its lander can collaborate with the MRO during its mission.

InSight
InSight can now join this prestigious crew at Mars, performing tasks like none that have come before it. Its ability to look underneath the surface is truly exciting and unique.

Opportunity
Spirit's surviving sibling Opportunity has been travelling across Mars since 25 January 2004, and clocking up an amazing odometer reading of over 45 kilometres (28 miles).

Curiosity
Curiosity is a car-size rover carrying multiple instruments that are deeply analysing the climate and geology of Mars, in particular the Gale Crater.



The lander's arm is vital to placing the SEIS and HP³ instruments onto Martian soil

ground. Along with the radio science instrument, the Rotation and Interior Structure Experiment (RISE), this tactical trio will be at the forefront of the interior investigations.

Each instrument has been carefully planned and created to perform a very specific task. SEIS will be the first seismometer to Mars in 40 years, and will listen out for tremors that could come from marsquakes, meteorite impacts or even possibly magma churning deep underneath the Red Planet's surface. In fact, this Martian stethoscope is so sensitive it can pick up vibrations smaller than a hydrogen atom.

"SEIS will be placed on the ground by a robotic arm and will 'listen' for the small (fractions of a nanometre) ground vibrations due to seismic waves that have travelled through the planet from distant marsquakes," says Banerdt. "Analysis of these waves will allow us to create a 3D picture of the inside of the planet."

The InSight team also have plans to collaborate with the Mars Reconnaissance Orbiter (MRO), which will be on the lookout for meteorite impacts. When the seismometer detects a meteoritic impact, the MRO and its meticulous High Resolution Imaging Science Experiment (HiRISE) camera will scout out the fresh crater.

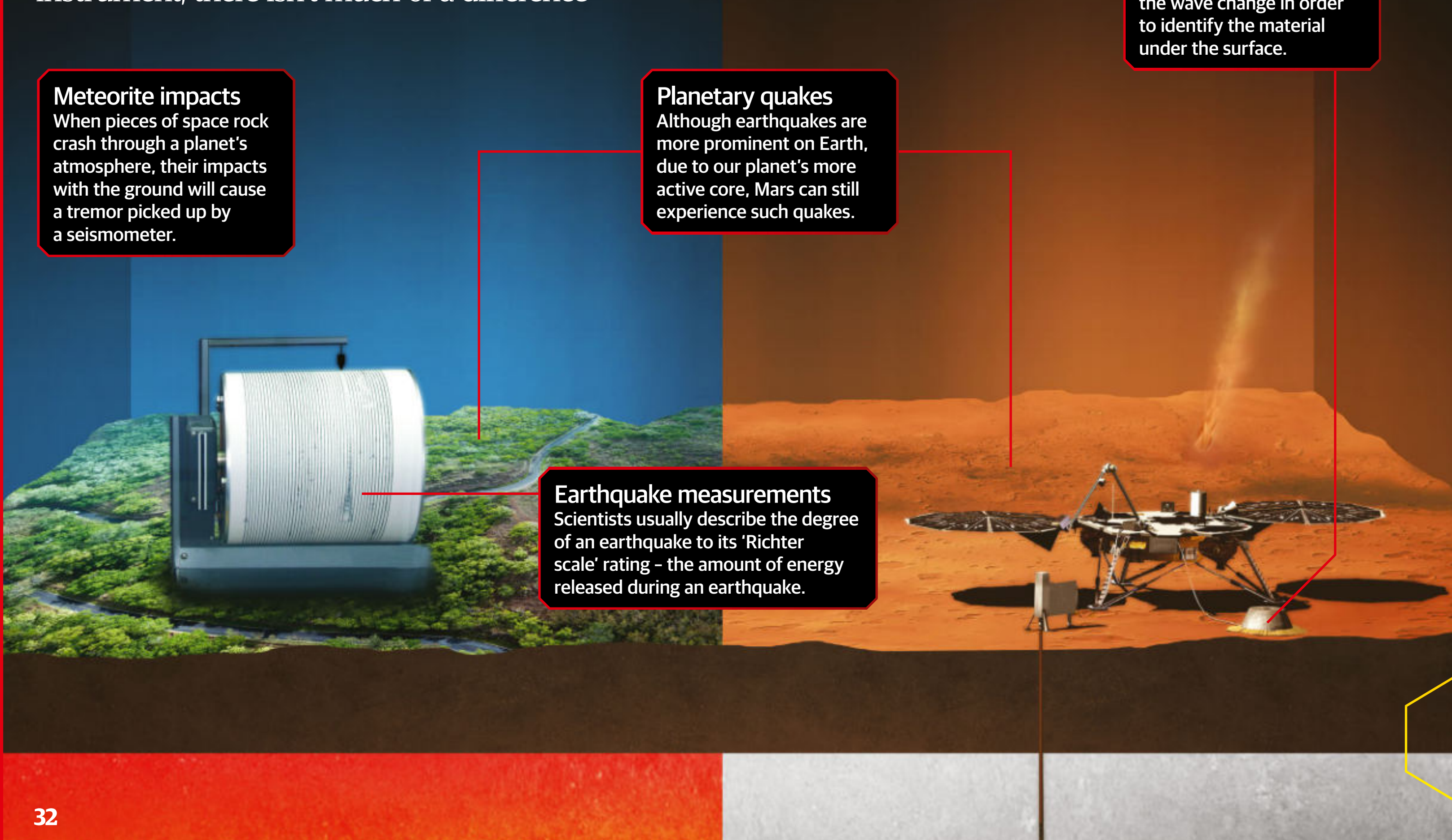
Dr Matt Golombek has worked on many Mars missions prior to InSight

Alongside SEIS is a drill that will take the planet's temperature. HP³ will make its way five metres (16 feet) down into the Martian crust. This is just 10 per cent of Mars' overall crust, but it is a good enough depth to allow astronomers to analyse the heat that comes from deep within the planet. The heat flowing underneath the surface reveals how active the planet is. On Earth, we are well aware of a region of magma churning beneath our crust which drives our tectonic plates and heats up our planet. The heat flow within Mars could be compared to Earth's and reveal that both were formed from the same substances, and if they aren't, then why not. "We're essentially doing the same thing anyone would do on a campout, but we're putting our stake down on Mars," says Dr Suzanne Smrekar, InSight's deputy principal investigator.

"Getting well below the surface gets us away from the Sun's influence and allows us to measure heat coming from the interior," says Smrekar. "InSight is going take the heartbeat and vital signs of the Red Planet for an entire Martian year, two Earth years. We are really going to have an opportunity to understand the processes that control the early planetary formation."

Measuring marsquakes and meteoric impacts

When comparing a seismometer on Earth to InSight's SEIS instrument, there isn't much of a difference



The solar arrays for the lander were extensively tested and cleaned at Lockheed Martin Space Systems, Colorado, United States

Not detached from the lander, but equally important, is RISE. With two antennae fitted on the lander deck, highly detailed X-band radio signals will be sent between InSight and the Deep Space Network dishes on Earth, allowing us to confine InSight's position to within a couple of centimetres every day. "This is enough to determine the direction of Mars' rotation pole and any wobble that it exhibits. This wobble is connected to the properties of the core, and will yield its size and density [which is related to its elemental composition]," explains Banerdt.

The way that InSight and the Deep Space Network determine the wobble of Mars is the same way a person's ears perceive the change of a siren's sound as it travels either towards or away from them. For example, if a police car has its siren on and it is speeding away from you, you will hear a relatively low-pitched sound. Then, when it's speeding towards you, the pitch is much higher. This is known as the 'Doppler Effect'. As the police car moves away, the siren's sound waves are stretched into a longer wavelength, and therefore a lower pitch. As the police car narrows the distance between the siren and you, it causes the sound's wavelength to shrink and creates a higher pitch.

This technique has been carefully developed to improve the accuracy of InSight's position and tell us if there is a metal core or a liquid molten core causing a planetary wobble. Also, RISE will be able to see how this wobble changes over time due to seasonal changes at the poles of the Red Planet. As the season changes from winter to spring, the frozen carbon dioxide at the poles sublimates – changes from solid to gas – affecting the rotation of the planet and therefore changing the length of a sol. RISE can track these changes throughout the course of its mission.

"Getting well below the surface… allows us to measure heat coming from the interior" **Dr Suzanne Smrekar**

The data collected will not only have long-standing and fruitful benefits for our understanding of Mars, it will also provide astronomers with valuable resources for future missions. As Banerdt explains, "Our meteorological data will be important in characterising the Martian environment for future human visits. More indirectly, the scientific understanding of the planet that InSight supplies will serve as a foundation for whatever research that people will carry out on the surface of Mars."

As for how long this mission will last? Who knows! Although the primary mission is only scheduled for one Martian year, we have seen many Mars missions function way beyond their primary mission lifetimes. The best example would have to be the Opportunity rover. The rover was only built for a 90-sol mission in 2004, and at the time of writing it is still operational, thus completing the first ever 'Martian Marathon' with a finish time of about 11 years and two months. It has now travelled over 45 kilometres (28 miles) travelled in that time, which is a remarkable achievement. And with over 2.4 million names placed on a microchip attached to the InSight lander, people worldwide will have their boarding pass ready as this historic expedition aims to change our cosmic understanding.

Vice President Mike Pence (left) visited the InSight lander at Lockheed Martin Space Systems

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HOW YOU CAN TRACK THE SPACEX TESLA

From the streets to space, Elon Musk's Roadster is now making its way to Mars. Here's what you need to locate it

Reviewed by Lee Cavendish

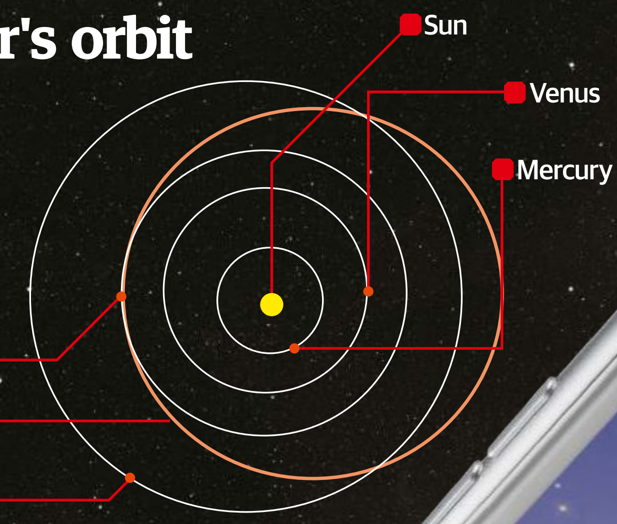
February 2018 marked a momentous occasion in space flight as Elon Musk's SpaceX tested the launch of its Falcon Heavy rocket. This payload not only proved it is capable of sending humans back to the Moon, and even beyond, but it achieved this by also showing that its boosters can be saved and reused, potentially dropping the price of a space launch by a factor of ten.

This launch had a payload that only an eccentric billionaire could pull off: in the tip of Falcon Heavy, and now travelling towards the orbit of Mars, was one of Musk's own Tesla Roadsters. With 'astronaut' Starman at the helm, dressed up in SpaceX's futuristic spacesuit, the Roadster will continue in its orbit, stretching beyond Mars and back to Earth in a Hohmann transfer orbit. While it's on its travels, the Roadster has been designated the Satellite Catalog Number, or NORAD ID, 43205 and can be tracked using different software.

All About Space has picked out two standout apps capable of tracking its movements, as well as a website dedicated to monitoring Starman's journey. With a breakdown of these different programs, you will be able to keep up-to-date on its whereabouts as it travels through space, assuming that radiation from space hasn't torn it apart by then.

The Roadster's orbit

This type of orbit is the most fuel-efficient way of taking a payload between Earth and Mars. As Earth and Mars orbit the same centre of mass, the Sun, it makes sense to send a payload from Earth into an eccentric orbit also around the Sun while evading the orbit of Mars.



APP

Star Walk 2

For: iOS & Android **Cost:** Free, 'Satellite' extension package £0.99 ($0.99)

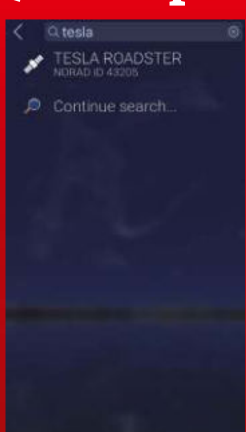
Star Walk 2 is a fantastic stargazing app, available on both Android and iOS. Its elegant design and in-depth archive of celestial objects is what makes it incredibly popular amongst astronomers. The fact that it is one of the few apps that has the Tesla Roadster within its database is what makes it an ideal app for this purpose. By having the night sky at your fingertips, you see where the Roadster should appear in the night sky if we were able to locate it with observing kit.

The compass icon at the top left of the screen will activate the app's augmented reality feature, meaning you can spin around your room as you try and find the Roadster.

The Tesla Roadster will immediately become the focus of the screen, showing where it is at the current time of searching. At this point, Starman was making its way through the constellation of Aquarius.

Clicking on its name at the bottom of the screen will bring up vital statistics.

Quick tips & tricks



Once you have the satellites' information at your disposal, it is easy enough to find. All that needs to be done is search for 'Tesla' in the search bar. The only result that will come up is the 'TESLA ROADSTER: NORAD ID 43205'.

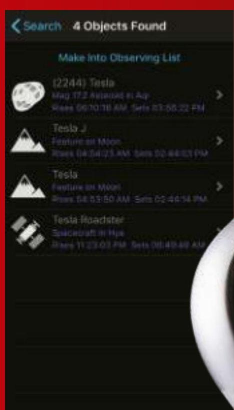
Unfortunately, the designers of the app haven't been able to draw up a 3D picture of the Roadster, hence the golden satellite with several question marks imprinted on.

There is information regarding the right ascension, declination, latitude, longitude, azimuth, altitude and elevation values. Depending on the time you fire up the app, this information can change and give you coordinates of the object in the night sky.

User guide

Before searching for the Tesla Roadster, be sure to 'Update Minor Body Orbit Data'. This will only take a couple of minutes at most, but it is essential for making sure the Roadster is included in the satellite database.

When searching for 'Tesla', it is suprising to see that there is more than one thing named Tesla in space. There are also two features on the Moon and an asteroid, but it's the spacecraft that's wanted.



Having clicked on the intended target, its information will appear. With information ranging from its basic information to its orbital parameters, there is much to learn about the Roadster's journey from just this section.

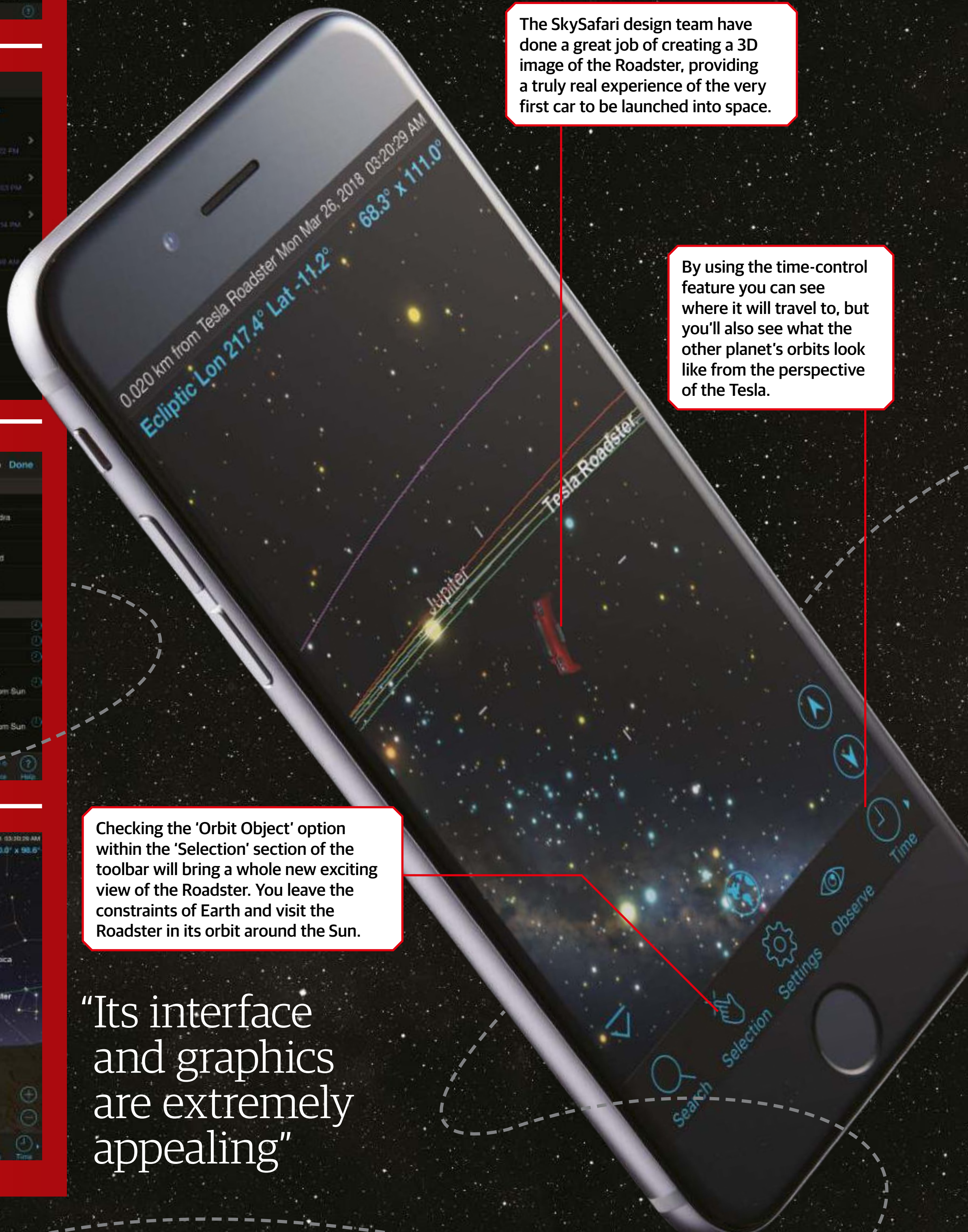
The bullseye icon labelled 'Center' at the bottom left of the screen will bring the Roadster to the centre of your screen, allowing you to see which constellation it's hiding in at the time. By also using the time-control feature you can see which constellation it's hopping to next.

APP

SkySafari 6 Pro

For: iOS & Android **Cost:** £38.99 ($39.99)

SkySafari 6 Pro is a recently released stargazing expert. With a catalogue of over 100 million stars and 750,000 Solar System objects, this app leaves no stone unturned. The information accessible on this iOS-exclusive app about the Roadster alone is incomparable to other apps on the marketplace. It is not just the database that makes this app a sensation, though, as its interface and graphics are extremely appealing. These features can make any astronomer immerse themselves, and with the option to switch your view from being on Earth to the Roadster in space makes for a highly enjoyable experience.



The SkySafari design team have done a great job of creating a 3D image of the Roadster, providing a truly real experience of the very first car to be launched into space.

By using the time-control feature you can see where it will travel to, but you'll also see what the other planet's orbits look like from the perspective of the Tesla.

Checking the 'Orbit Object' option within the 'Selection' section of the toolbar will bring a whole new exciting view of the Roadster. You leave the constraints of Earth and visit the Roadster in its orbit around the Sun.

> "Its interface and graphics are extremely appealing"

WEBSITE

whereisroadster.com

For: Mac & Windows **Cost:** Free

Soon after the Falcon Heavy launch, Ben Pearson, who is an engineer with a keen eye for space exploration, created a new website dedicated to tracking Starman's journey. This work relies on NASA's updated Jet Propulsion Laboratory (JPL) HORIZONS data, which keeps a record of 755,699 asteroids, 3,512 comets, 178 planetary satellites, eight planets and one star. However, it's just the one satellite that it needs to be worried about, and **whereisroadster.com** does an excellent job of collating this information and showing the uninterrupted position of Roadster, terrestrial objects and the Sun.

'The Chart' presents the Roadster's orbit (shown in green) passing beyond the orbit of Mars (shown in red), but not quite reaching the orbit of Ceres (shown in grey).

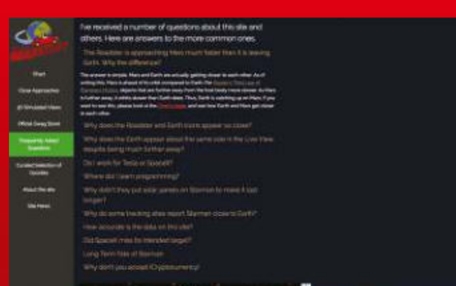
By adjusting the time bar at the bottom of the chart, you can see the positions of the terrestrial planets, Roadster and sometimes Ceres as they orbit the Sun until the last month of the year 2020.

Particularly around October 2020, there will be an extremely close encounter with Earth, Mars and the Roadster.

Bonus features

The homepage welcomes you with a simulated view from the Tesla, a chart containing the main orbits of inner Solar System objects and a fun-fact list, which is continuously being refreshed.

'Upcoming Key Milestones' is a noteworthy subsection of the website, as it has detailed any close encounters and, on the contrary, the farthest points between objects.

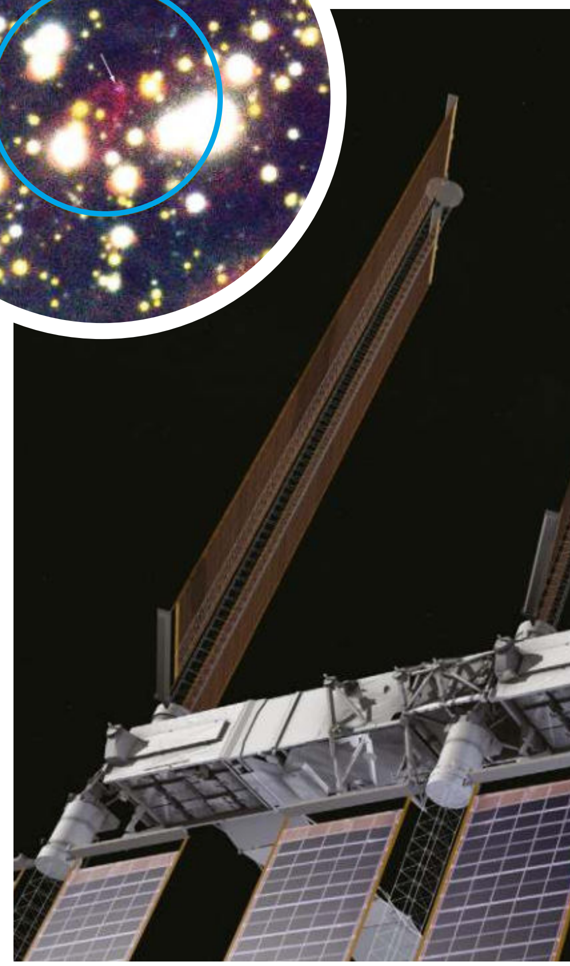


The 'Long Term Fate of Starman' is worth a read; it briefly describes a possible recapture mission in 30 years and a link to a scientific paper detailing simulations of Starman's future.

THE HUNT FOR QUARK STARS

The search is on for a strange object somewhere in between a neutron star and a black hole

Written by Abigail Beall



When you drill down into the most fundamental building blocks of nature, strange things begin to happen, governed by the bizarre rules of quantum mechanics. These give rise to even stranger phenomena; some that have been observed and some that remain purely theoretical.

One example of these theoretical phenomena is a quark star. The idea is that the material that makes up neutron stars, thought to be some of the densest objects in the universe, when put under enough pressure, can break down into their constituent parts: quarks. This idea was first put forward in the 1960s, but to this day it is still unknown whether quark stars could exist. Theoretically and observationally it's difficult to tell whether or not they could happen in reality, but scientists around the world are having a go.

The Standard Model of particle physics, which is the best description we currently have of the tiniest fundamental particles and how they behave, says the fundamental particles can be broken down into two categories: fermions and bosons. Fermions, which can be further categorised into quarks and leptons, make up all matter as we know it. Leptons include the electron, muon and tau, while there are six types or 'flavours' of quarks, which combine in different ways to create different particles, called baryons. Examples of baryons include the neutron, which is made up of one up and two down quarks, and the proton, which is made up of two up and one down quark.

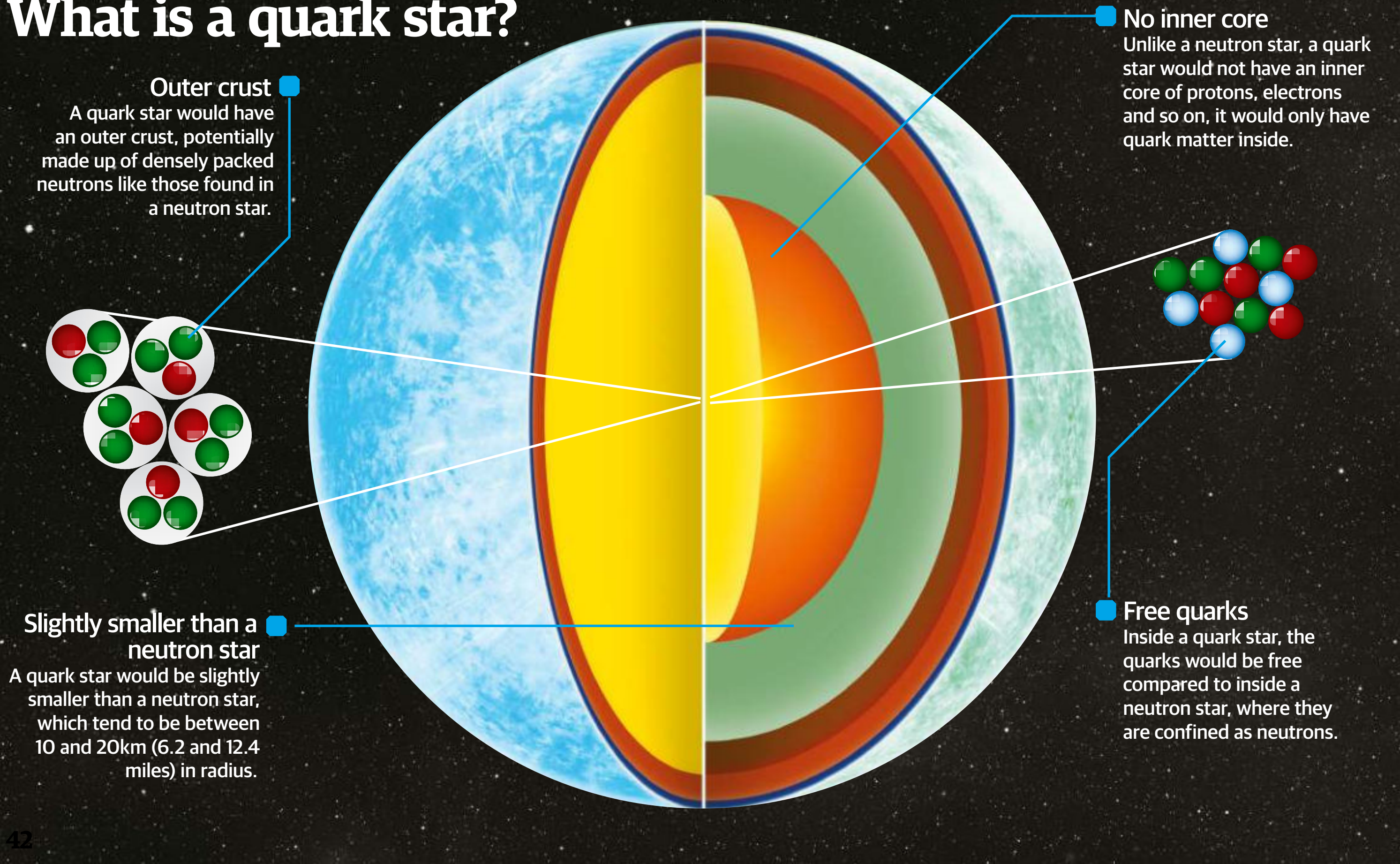
In atoms, the nucleus is made up of a combination of protons and neutrons, orbited by electrons. However, in the extreme conditions of space, electrons and protons can be crushed together to form neutrons, in something called a neutron star.

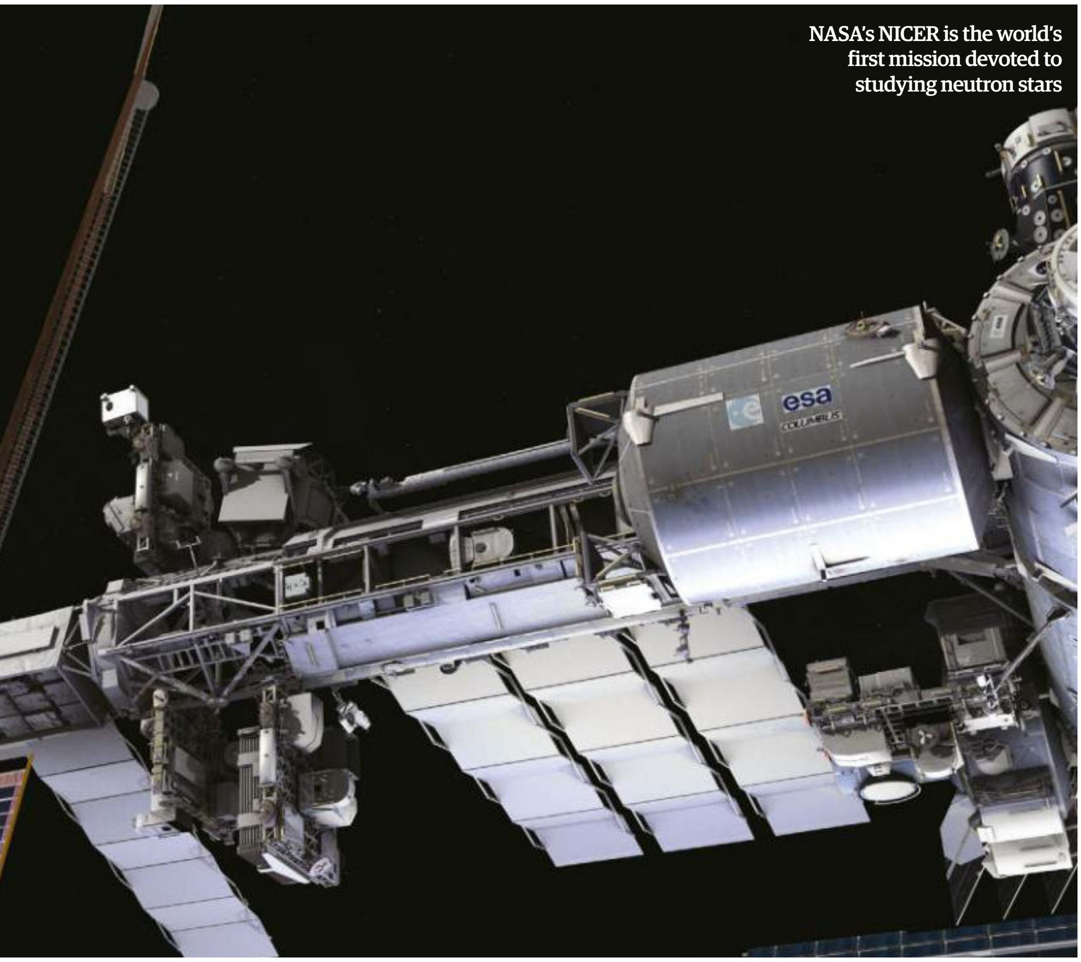
Neutron stars are formed in a very specific situation, born from a supernova explosion of a massive star that does not have quite enough mass to form a black hole. The massive star, between four- and eight-times the mass of the Sun, having run out of fuel explodes, representing the end of its life. What's left behind is a core of densely packed material: neutrons. With around 1.4 solar masses packed into a radius of around 10 kilometres (6.2 miles), neutron stars are unimaginably dense. How dense is that? Well, one teaspoon of neutron star matter would weigh over 1 billion tonnes on Earth.

With this huge weight packed into such a small space, neutron stars are subjected to incredibly strong forces of gravity. The only reason they do

“They might be possible in a very narrow set of circumstances, somewhere between a neutron star and a black hole” **Dr Paul Sutter**

What is a quark star?





NASA's NICER is the world's first mission devoted to studying neutron stars

not collapse further in on themselves is due to something called degeneracy pressure; one of the strange things that happens when you look at matter on the tiniest scale.

The rules of quantum mechanics dictate that no two fermions can occupy the same state. This is called the Pauli exclusion principle. What it means is that, even once a star's core up to three-times the mass of our Sun collapses under its own weight, gravity is not enough to force the neutrons closer together. The neutrons arrange themselves into higher and higher energy levels in order to prevent them from violating the exclusion principle, and this creates an effective pressure, which keeps them from collapsing. If the collapsed core is heavier than somewhere around three solar masses, however, its gravity will be enough to overcome neutron degeneracy, and it will end up as a black hole.

The same thing can happen with smaller stars, too. Stars too small to end their lives in a huge, dramatic explosion fizzle out into a hot, dense core known as a white dwarf. However, when a white dwarf is more than 1.4-times the mass of the Sun, it collapses under its own weight because the electron degeneracy pressure is not enough to keep it stable and may become a nova or even a supernova.

China's enhanced X-ray Timing and Polarimetry mission (eXTP) aims to study neutron stars, black holes and quark stars

What's so weird about quark stars?

While they would be difficult to identify, it is theoretically possible for quark stars to exist

A rare occurrence
The circumstances to create them would have to be just right; slightly too heavy for a neutron star but too light for a black hole.

Unstable stars
If quark stars are created, they may not be stable enough to exist for a long time.

What do they look like?
There's very little difference between a quark star and a neutron star, so finding them will be difficult.

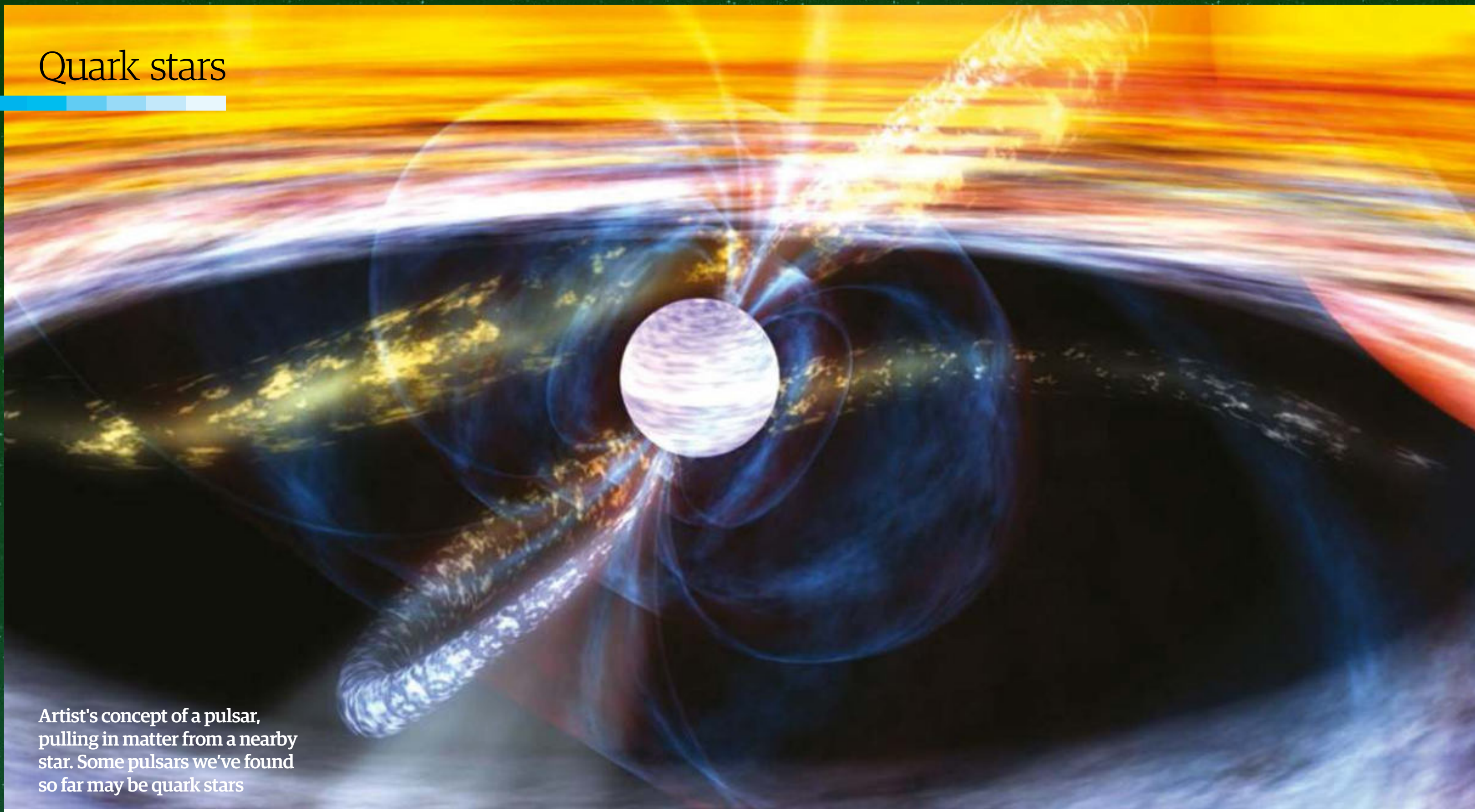
Quark physics
We do not understand the laws of quark matter well enough to say whether a quark star could exist.

Degeneracy pressure
Neutron stars are held up by neutron degeneracy pressure. Quarks have a degeneracy pressure too, so there could be quark stars.

Spotting them
Quark stars should be slightly smaller, with some differences in the way they rotate compared to neutron stars.

Hard to recreate on Earth
Mimicking the conditions inside a quark star on Earth would be almost impossible.

Neutron star cores
It is possible neutron stars actually host a quark-supported core in their centres, but we do not understand quark physics well enough to say for sure.



Artist's concept of a pulsar, pulling in matter from a nearby star. Some pulsars we've found so far may be quark stars

But it doesn't end there. There is one theory that suggests there could be something in between a neutron star and a black hole. When the neutron star is too massive to be propped up by neutron degeneracy pressure, the neutrons could break open, leaving only quarks. Since quarks are also fermions, they could provide their own degeneracy pressure. This leaves us with the theoretical quark star, a star made up of a mass of quarks keeping itself up by the degeneracy pressure quarks provide.

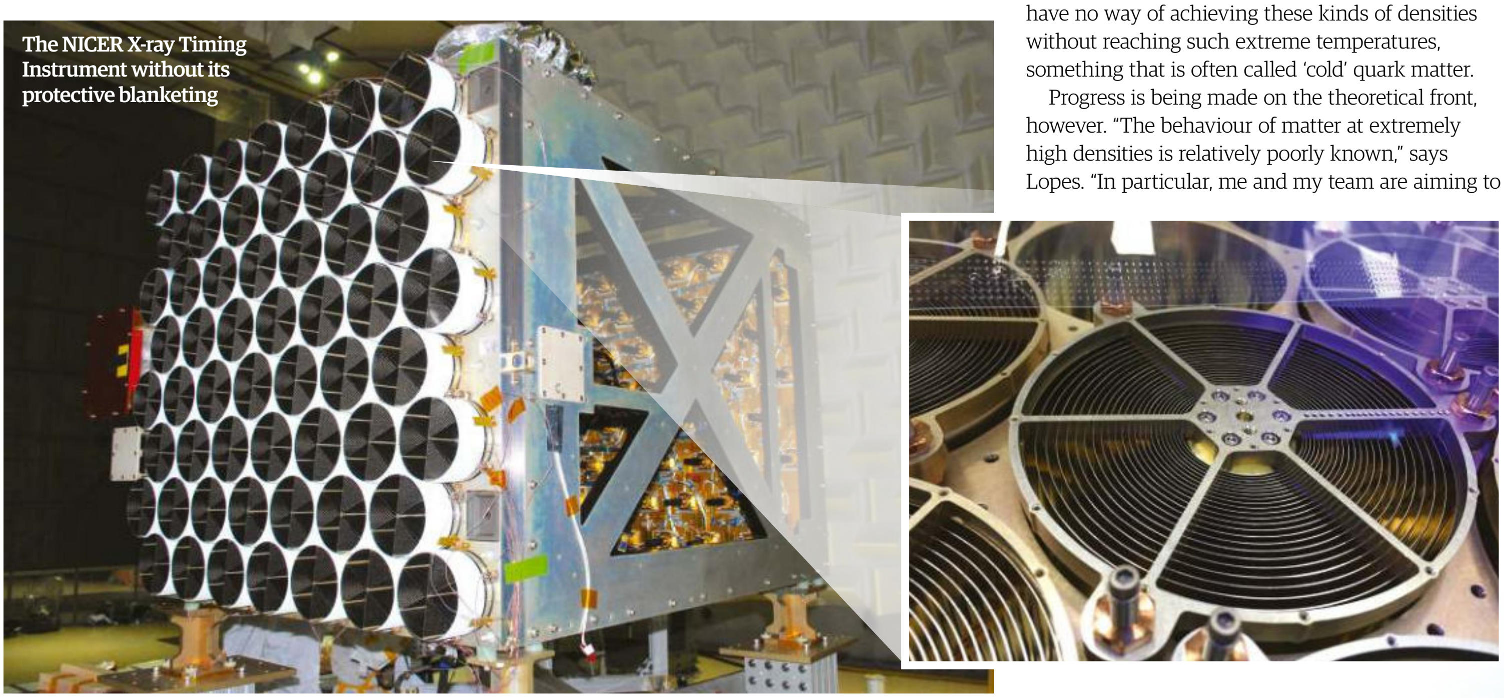
There is another proposed category of star called a strange quark star which, as the name suggests, is only made up of strange quarks; one of the six quark flavours. It is thought these quark stars would have an outer layer of neutron star material, so would appear exactly like a neutron star.

The first point is that if they even do exist, quark stars would be rare. There may only be a tiny window when the conditions are not quite in place to make a neutron star, but not quite enough for a black hole. And that's if they do exist.

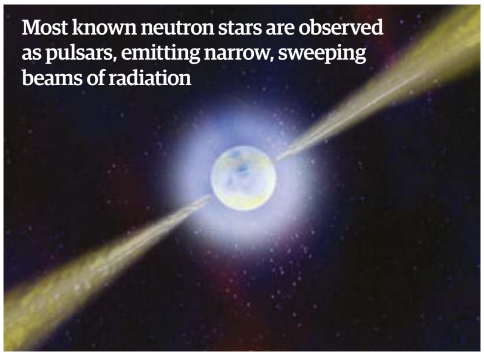
"Theoretically they might be possible in a very narrow set of circumstances, somewhere between a neutron star and a black hole," says Dr Paul Sutter, an astrophysicist at The Ohio State University. "We're not sure yet if quark stars, even if they're produced in nature, are stable enough to exist for any decent amount of time." The existence of quark stars "is well motivated from a theoretical point of view" says Dr Ilidio Lopes from the University of Lisbon, Portugal, who studies the state of matter at extremely high densities, like one may find in a quark star. "Nevertheless, to find them among the population of neutron stars in the Milky Way is a difficult challenge."

If quarks did exist, they would be made up of something called quark matter, a melting pot of quarks and gluons, which is also known as quantum chromodynamics (QCD) matter. On Earth, it is difficult to create the conditions in which quark matter could survive; one would need temperatures or densities billions of times that which can be created in a laboratory. Physicists are trying to create quark matter in particle colliders, but so far all they have achieved is an extremely hot quark-gluon plasma which lasts only moments before decaying. In stars, it is the density that would provide the conditions to create quark matter, but on Earth we have no way of achieving these kinds of densities without reaching such extreme temperatures, something that is often called 'cold' quark matter.

Progress is being made on the theoretical front, however. "The behaviour of matter at extremely high densities is relatively poorly known," says Lopes. "In particular, me and my team are aiming to



The NICER X-ray Timing Instrument without its protective blanketing


Most known neutron stars are observed as pulsars, emitting narrow, sweeping beams of radiation

> "To find them among the population of neutron stars in the Milky Way is a difficult challenge"
>
> **Dr Ilidio Lopes**

achieve a better understanding about how baryonic matter behaves in the core of these compact stars." This line of research will help us understand more about whether quark stars could exist and, if so, how they may appear.

While astronomers hunt for quark stars in space, theoreticians like Lopes are using data gathered on Earth. "In our work we are taking advantage of an important contribution coming from nucleus-nucleus collision experiments like the Large Hadron Collider (LHC), among others, that can help us to better characterise the matter inside neutron stars and their cousins, like quark stars," he says.

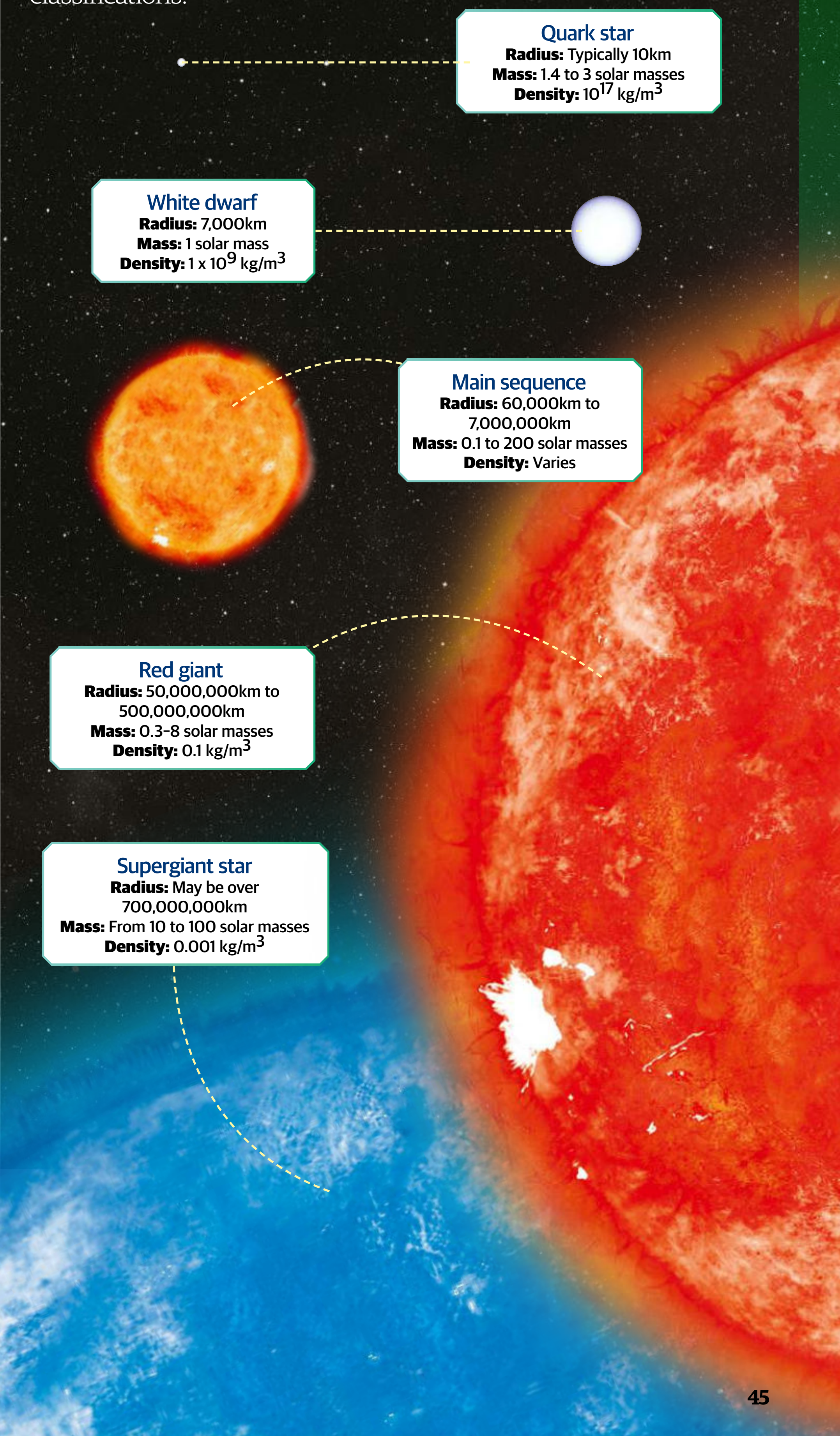
What about looking for quark stars themselves, out in space? Well, that seems quite difficult too: "Any mission that studies neutron stars is also automatically hunting for quark stars," says Sutter. "On the surface, literally, there's very little difference between a quark star and a neutron star. They're both hot, dense, bright objects, but quark stars will be a little bit smaller and have some other quirks in the way they rotate, so by closely examining their properties we might be able to spot one."

"The Milky Way is estimated to have around one billion neutron stars, from which it is expected that 200,000 of the neutron stars are pulsars," says Lopes. "Until now astronomers have discovered slightly less than 2,000. It is possible that some quark stars are hidden among pulsars."

"There might be some tiny differences in the electromagnetic signature between quark and neutron stars, if it was easy to detect, we would've found some by now," adds Sutter. It is also possible neutron stars actually host a quark-supported core in their centres, but we do not understand the physics well enough to say for sure.

The size of stars

How do quark stars measure up to other classifications?



This does not mean scientists are giving up, however. The next generation of space-based telescopes will be the most powerful yet, and if anything has the ability to find a quark star, it will be them. "The most likely missions to look for such types of exotic stars are dedicated X-ray observation telescopes, such as the Neutron star Interior Composition Explorer (NICER) and Large Observatory for X-ray Timing (LOFT)," says Lopes.

NICER is a NASA mission that was launched to the ISS on 3 June 2017, dedicated to studying neutron stars, including pulsars. It could end up being the one to perform important tests that could lead to the discovery of quark stars. NICER will study the spectra of several neutron stars in the soft X-ray regime. This will allow astronomers to test current models of neutron stars to a greater accuracy, Lopes says, "by complementing the standard test of mass-radius relation of compact objects with a detailed measurement of the spectral atomic line profiles of such compact stars.

"In quark stars it is expected that their atomic line profiles depend not only on the mass and

> "It is also possible neutron stars host a quark-supported core"

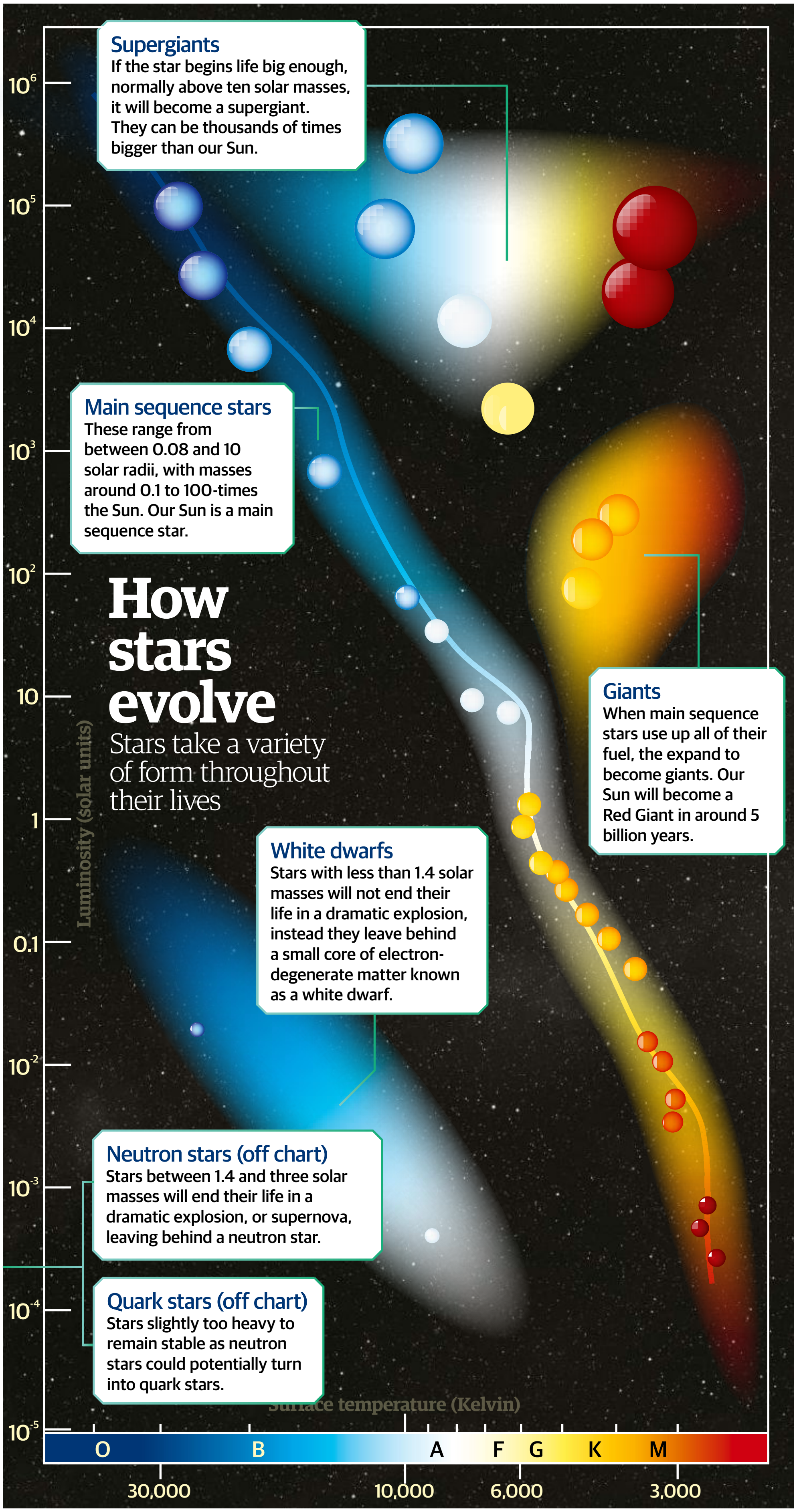
radius of the stars, but also on other stellar parameters such as their moment of inertia and their quadrupole moment," says Lopes. "Such high precision measurements will allow for stringent constraints on the properties of dense matter inside neutron stars, and possibly point us in the direction of the discovery of quark stars."

Another space telescope, China's enhanced X-ray Timing and Polarimetry mission (eXTP), could help find the answer. The mission will be launched by 2025, and its aim is to study some of the most powerful and violent objects in space, including black holes, neutron stars and even quark stars.

Will we ever find them? "The discovery of a new class of object will be a challenge, but by taking advantage of a combined effort between a profound theoretical understanding about how matter should behaviour in extreme high-density conditions, and reliable models of neutron stars and quark stars, it should be possible to determine if such compact objects can be found in the universe," says Lopes.

"There is some hope that this could be achieved in the near future by predicting how different these exotic stars are from a typical neutron star," he says. For instance, a quark star is denser than a typical neutron star. "As such, many other properties will be different from the ones found in a neutron star. In particular it was found that a putative quark star will lead to a supernova explosion 100-times brighter than a typical supernova."

Recent discoveries of very compact objects with very high densities, like the millisecond pulsars SAX J 1808.4-3658 and RX J1856.5-3754, are among the possible candidates for quark stars.



THE RETURN OF TIANGONG-1

Towards the latter days of March and the first days of April, the 'out-of-control' Chinese space station finally crash back to Earth

The Chinese space station Tiangong-1 has been without contact since March 2016, but made a resurgent appearance over the Easter weekend when it broke up over the Pacific Ocean. The 10.4-metre-long (34-foot) module was China's first prototype space station of the Tiangong program, translated as 'Heavenly Palace' or 'Celestial Palace', when it was launched in September 2011. This marked the first step in China creating a third-generation space station, much like Mir and the International Space Station, but now it is the biggest man-made object to re-enter the Earth's atmosphere in over a decade.

The aim of Tiangong-1 was to test and improve upon the techniques involved in the orbital rendezvous and docking on board a space station. Ever since its launch, the orbit of Tiangong-1 has slowly decayed due to the ever-so-faint

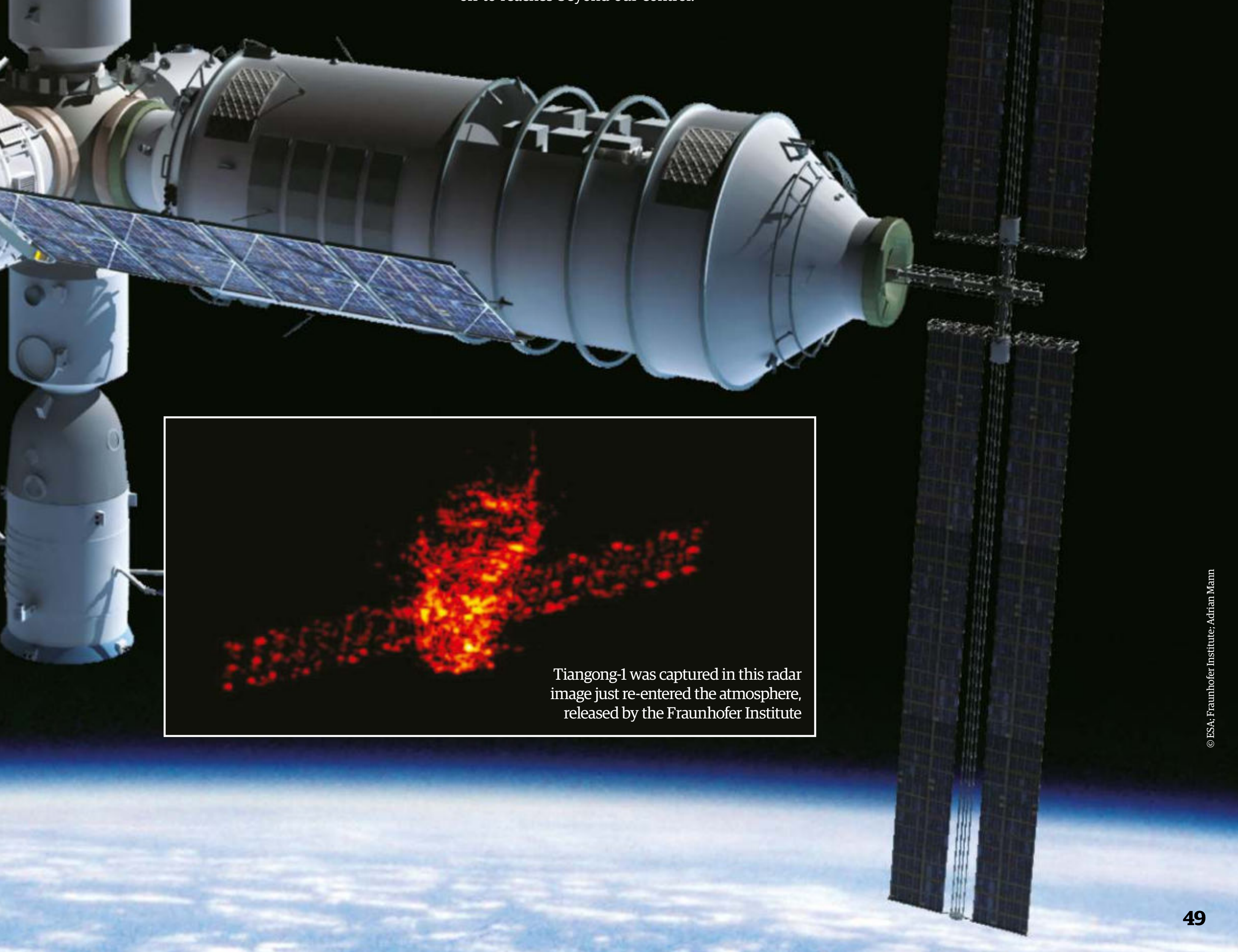
"It is the biggest man-made object to re-enter the Earth's atmosphere in over a decade"

atmospheric drag, even at high altitudes of 300 or 400 kilometres (186 to 249 miles). In fact, several 're-boost manoeuvres' were undergone to maintain an altitude between 330 and 390 kilometres (205 and 242 miles).

It was known from the start that this prototype would reach its demise with a controlled re-entry back to Earth. The ground controllers would have told the engines to fire, directing the burning spacecraft towards a huge, unpopulated area in the South Pacific Ocean. Unfortunately not everything goes to plan, and in March 2016 it was announced that Tiangong-1 had lost all functions, but they confirmed it still retained its structural integrity. Since then, scientists have been trying to constrain the re-entry dates and regions for this 8.5-tonne (18,753 pound) hunk of metal.

In mid-March 2018, the European Space Agency's Space Debris Office (ESOC) announced that the currently unmanned Tiangong-1 would most likely grace us with its presence between 30 March and 2 April 2018. However, ESOC emphasised that this estimated window is "highly variable". Not only that, but the re-entry would take place between 43 degrees north and 43 degrees south. The probability of an impact at the time were higher in places such as northern China, the Middle East, central Italy, northern Spain and the northern states of the United States, New Zealand, Tasmania and parts of South America and southern Africa. Although this seems like a wide range of 'targets', the chances of being hit by a piece of Tiangong-1 are about "10 million-times smaller than the yearly chance of being hit by lightning" as stated by ESOC.

The subject of space debris re-entry, and it potentially being harmful for humans, is a topic that is being widely discussed throughout the astronomical community. ESA is currently leading the way in terms of removing space debris, as they remain committed to monitoring, tracking and removing space debris using a variety of techniques and technologies. It has proven to be problematic in the past, for example on the 10 February 2009, the operational Iridium-33 satellite collided with the out-of-service Kosmos-2251 satellite at 10 kilometres (6.2 miles) per second. The resulting debris from this first-ever satellite collision caused a medley of fragments to scatter off to reaches beyond our control.



An artist's impression of Tiangong-3, which was originally planned to launch in 2015. The space station was cancelled

Tiangong-1 was captured in this radar image just re-entered the atmosphere, released by the Fraunhofer Institute

HOW WE'RE **BEATING CLIMATE CHANGE…** *FROM SPACE*

Earth-orbit gives us the perfect vantage point for taking steps to save the planet

Reported by Libby Plummer

Climate change is one of the greatest challenges facing our planet today. Comprising a broad range of global phenomena – the primary cause being the burning of fossil fuels – it includes global warming, sea level rises, ice mass loss, and extreme weather.

While climate change skeptics inexplicably persist, some 97 per cent of scientists agree that climate-warming trends over the past century are most likely due to human activities, according to multiple studies published in peer-reviewed journals. Data unequivocally shows that global temperature has risen, oceans have warmed, ice sheets have shrunk, glaciers are retreating and sea levels are rising. Just this year, readings from NASA's Goddard Institute for Space Studies (GISS) in New York showed that February 2018 was the sixth-warmest February in 138 years.

So, how do we deal with such a problem? The response to climate change involves a two-pronged approach – mitigation and adaptation. The former involves reducing emissions and stabilising heat-trapping greenhouse gas levels in the atmosphere, and the latter focuses on adapting to climate change that is already happening or is expected to happen. This is where space comes in.

Space agencies around the world have a number of missions aimed at addressing climate change by gathering data from Earth observation missions. ESA's Climate Change Initiative (CCI) was launched in 2009 to meet the desperate need for climate data. "The aim of the CCI is to produce measurements of the Earth from space that have all been developed in a very similar way, using the same processes to look at satellite datasets over the land, oceans, ice, [and] the atmosphere," Andrew Shepherd, Professor of Earth Observation at the University of Leeds and science lead on the CCI ice sheet project, tells **All About Space**. "This is so anyone using any one of the datasets can be confident they've all been produced in the same way."

These standardised datasets are based on Essential Climate Variables (ECVs), which were developed by the Global Climate Observing System (GCOS). The ECV data is required to support the United Nations Framework Convention on Climate Change (UNFCCC) and the International Panel on Climate Change (IPCC). To date, the CCI has generated more than 100 datasets and 2.6 million files, comprising a massive 122 terabytes of data. The data is freely available online for climate researchers and policy makers to refer to.

A car hidden underwater for years is finally unearthed due to drought

Storms like Hurricane Irma could become more intense and destructive as a result of climate change

Much of the initiative's data is gathered by ESA's Copernicus programme, which is supported by a family of satellites called the Sentinels, as well as other non-ESA missions. Satellites have given us a new way of seeing the world and gathering information on inaccessible areas, making them a crucial element in the battle against climate change. As they remain in place for long periods of time, they can also show long-term global environmental changes on Earth that we might not necessarily be able to monitor from the ground.

Built specifically for the Copernicus programme, the Sentinel satellites carry instruments that can perform a range of tasks, including radar imaging and sea surface topography measurements. The Sentinel-5P, which is dedicated to monitoring air pollution, was the latest in the group to launch, blasting off from the Plesetsk cosmodrome on 13 October 2017. The Sentinel-3B is the next in line to be sent into orbit with a scheduled launch of 25 April 2018, and its wide-ranging mission will include taking vital measurements of ocean- and land-surface temperature, as well as forest cover.

Unsurprisingly, NASA also has a space-based programme for tackling climate change, known as the Earth Observing System (EOS), which is led by the flagship satellite Terra, the Latin name for Earth. Launched on 18 December 1999, Terra packs five instruments that work concurrently to observe Earth's atmosphere, ocean, land, snow, ice and energy balance. What's more, the on-board MODIS (Moderate Resolution Imaging Spectroradiometer) and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) instruments provide critical information for assessing and managing natural disasters and other emergencies.

Somewhat alarmingly, Terra was the subject of two cyber attacks in 2008, experiencing interference for a total of 11 minutes, with Landsat 7 also being targeted. However, despite the worrying

"Aside from ensuring ongoing awareness, another major challenge for climate experts is funding"

Forest fires are becoming more problematic due to rising temperatures in heavily-wooded areas

What's happening to Earth?

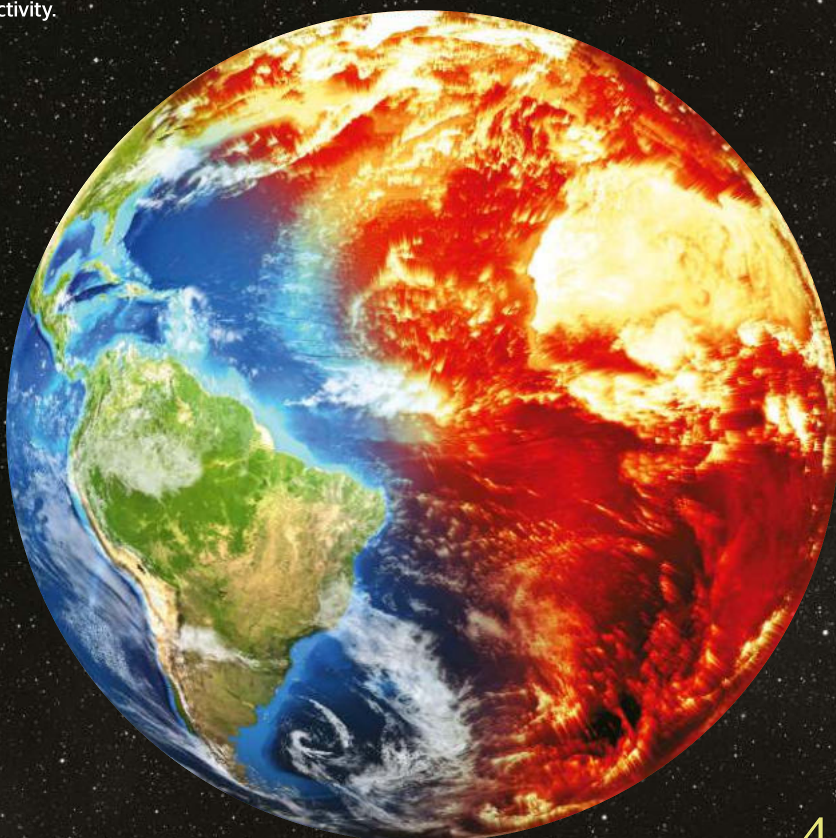
We can already see some of the measurable effects of climate change on the planet

97%
Scientific consensus
The percentage of climate experts that agree climate trends observed over the last century are likely a result of human activity.

286
GIGATONNES PER YEAR
Ice sheets
The Antarctica and Greenland ice sheets have been losing mass since 2002, with 127 and 286 Gigatonnes lost respectively per year since then.

2016
Global warming
2016 was the hottest year on record. 2017 was the second warmest and 2015 the third hottest.

30%
Biodiversity
Since Europeans started to colonise the Americas over 500 years ago, 30 per cent of biodiversity has been lost. This is expected to rise to 40 per cent unless steps are taken.



3.2mm
Sea level
Sea levels are currently rising at a rate of 3.2mm a year.

10%
Vegetation
Scientists estimate that around ten per cent of global carbon dioxide emissions come from deforestation.

250,000
Disease
Between 2030 and 2050, climate change is expected to cause 250,000 more deaths per year due to conditions like malaria and malnutrition.

1.0°C
Temperature
The world has warmed by about 1.0°C (1.8°F) since 1880. 17 of the 18 warmest years have occurred since 2001.

408ppm
PARTS PER MILLION
Pollution
Atmospheric CO_2 levels measured at Mauna Loa Observatory, Hawaii, continue to increase, with the latest recording of 408ppm in February 2018.

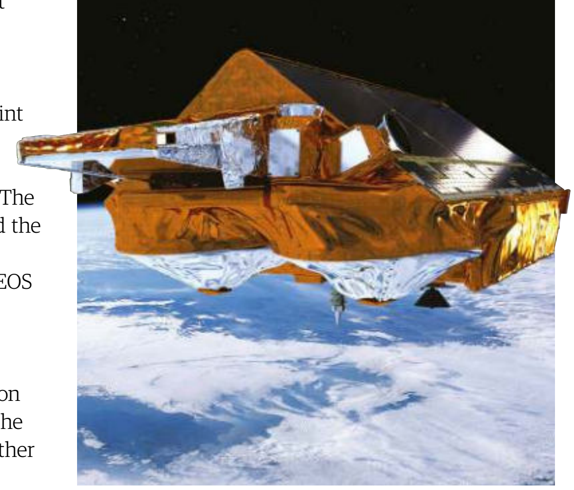
hack, no commands were successfully sent to the satellites and no data was captured. The hack was suspected to be tied to the Chinese military, though China denied any involvement. Thankfully, no similar incidents have been reported since.

Also making up NASA's climate change-monitoring satellite roster is the Afternoon Constellation, or A-Train. This group of Earth-monitoring satellites fly in a coordinated orbit like a train on a track, only 705 kilometres (438 miles) above the Earth's surface. Until recently the constellation was made up of six satellites, including NASA's Aqua, Aura, and Orbiting Carbon Observatory-2, the NASA-CNES Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and Japanese space agency JAXA's Global Change Observation Mission - Water (GCOM-W1). Until February 2018, the cloud-monitoring CloudSat was also part of the formation until its orbit was deliberately lowered following the loss of one of its reaction wheels – the flywheel used for making small, precise manoeuvres. While the CloudSat will continue its science mission, it will no longer fly as part of the A-Train.

Many of NASA's additional Earth observation satellites were launched in collaboration with other organisations. The Landsat mission is a joint programme with the United States Geological Survey (USGS) and is the longest continuous space-based record of Earth's land in existence. The original Landsat 1 satellite launched in 1972, and the upcoming Landsat 9 is due to launch in 2020.

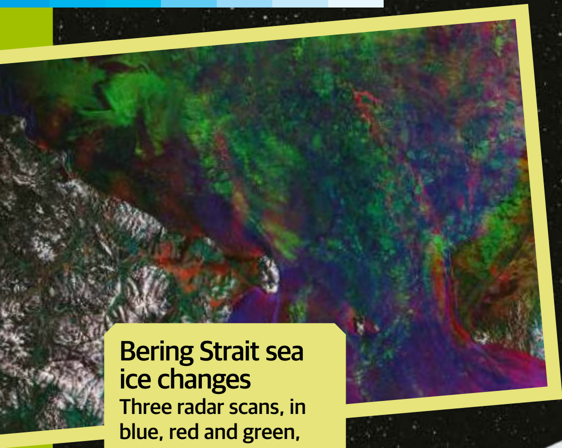
One of the latest instruments to join NASA's EOS operations in space was the Total and Spectral Solar Irradiance Sensor (TSIS-1), which became fully operational in March. This is designed to measure the total amount of sunlight that falls on Earth, and how that light is distributed among the infrared, visible and ultraviolet wavelengths. Rather than orbiting the Earth on a dedicated satellite,

ESA is working on funding a successor to the polar-gazing CryoSat satellite

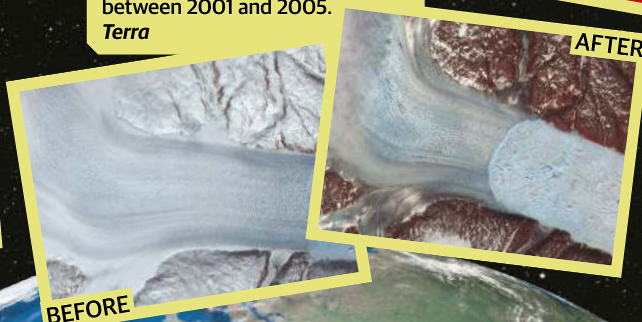


Evidence for climate change

Stunning images taken from space show the alarming impact on Earth

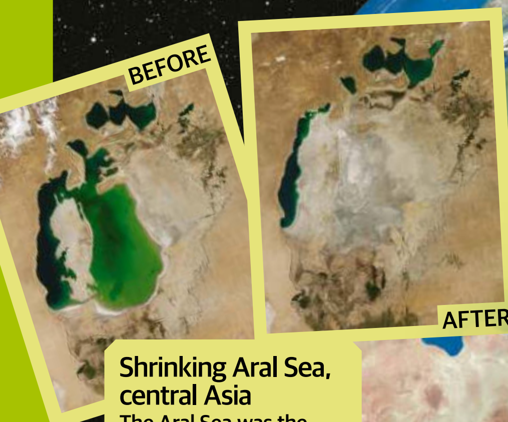


Bering Strait sea ice changes
Three radar scans, in blue, red and green, show how sea ice changed over four weeks in 2017 to 2018.
Sentinel-1



Helheim Glacier melt, Greenland
The Helheim Glacier is shown crumbling into icebergs, having retreated about 7.5 kilometres between 2001 and 2005.
Terra

Nordenskiöld Glacier, Greenland
The Nordenskiöld Glacier (above) is just one of many glaciers draining Greenland's ice sheet. ***Sentinel-2A***



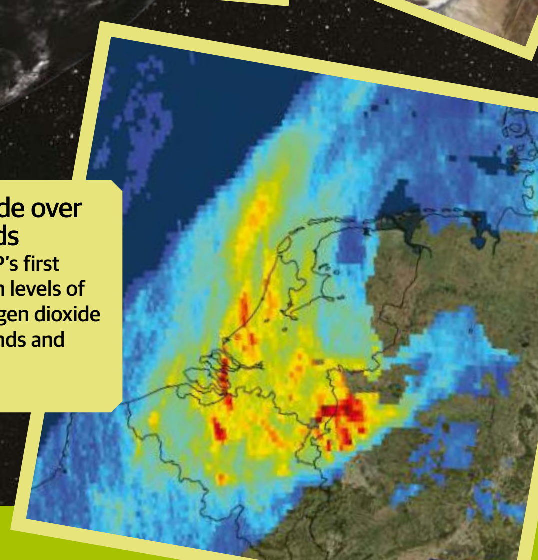
Shrinking Aral Sea, central Asia
The Aral Sea was the fourth-largest lake in the world until the 1960s, when the Soviets diverted water for crops.
Terra

Binhai new area growth, China
Astounding urban sprawl can be seen on China's coast between 1992 and 2012.
Landsat 7

Drying Lake Poopó, Bolivia
Bolivia's second-largest lake dried up again in 2016 due to drought and diversion of water sources.
Landsat 8

Columbia Glacier melt, Alaska
The Columbia Glacier has been in rapid retreat since 1980 and has thinned significantly.
Landsat 5/8

Nitrogen dioxide over the Netherlands
One of Sentinel-5P's first images shows high levels of atmospheric nitrogen dioxide over the Netherlands and west Germany.
Sentinel-5P



The six Sentinel missions carry a range of instruments for gathering data for the Copernicus programme

the TSIS-1 was installed on the International Space Station (ISS) after launching on a SpaceX Falcon 9 on 15 December 2017. The orbit of the ISS permits observations not offered by standard satellites.

"TSIS-1 extends a long data record that helps us understand the Sun's influence on Earth's radiation budget, ozone layer, atmospheric circulation and ecosystems and the effects that solar variability has on the Earth system and climate change," said Dong Wu, TSIS-1 project scientist at NASA's Goddard Space Flight Center, in a statement in March.

The Japan Aerospace Exploration Agency (JAXA) also has an initiative called the Global Change Observation Mission (GCOM) and, on 23 December 2017, it launched the GCOM-C1 satellite, nicknamed SHIKISAI, which is aimed at forecasting future global climate trends. Collecting data on clouds, aerosols, ocean colour, vegetation and snow and ice, the satellite is expected to gather a complete picture of the Earth every two to three days.

In October 2017, a new Earth observation project, backed by £75,000 in study phase funding, from the UK Space Agency was announced. The TARDiS (Terahertz Atmospheric/Astrophysics Radiation Detection in Space) is designed to offer new insights on how the composition of the atmosphere is affected by climate change. The instrument is designed to fit on to the new Bartolomeo platform on the ISS. Built by Airbus, the platform is due attach to the European Columbus module of the ISS in mid-2019, and will play host to instruments from space agencies and private companies covering a wide range of applications including robotic, astrophysics and, of course, Earth observation.

"The development of TARDiS, based on novel and ground-breaking Terahertz sensing technology, will not only enable us to measure the global distribution of atomic oxygen in the upper atmosphere and to understand how this region affects the climate of Earth, but will also help us better comprehend the process of star formation and the origin of the universe," said Dr Jolyon Reburn, head of the Earth Observation Division at RAL Space in a statement announcing the project.

Like ESA, NASA combines its climate data from space with information gathered on the ground to create as full a picture as possible of changes in the Earth's environment.

"The datasets that we produce – we make them publicly available for anyone else to use," says Shepherd, whose team produces measurements on how much ice has been lost from Antarctica and Greenland for ESA's CCI. "We make use of them ourselves for scientific purposes and we also deliver them to third parties as operational datasets. For example, the sea level rise estimates are part of the European Environment Agency's climate indicator series, and they were formerly part of the EPA's [United States Environmental Protection Agency's] climate indicator series – before it was abolished by the present Administration," Shepherd tells **All About Space**.

> "[CryoSat] is particularly important to us because it's the only satellite designed to look at the polar regions" **Prof Andrew Shepherd**

Polar bears are one of many animals that face extinction if climate change goes unchecked

Since the beginning of Trump's Presidency, the EPA's website has been altered to scrap various mentions of climate change and related data and also makes remaining information harder to find, leading to accusations of scientific censorship. Actions like this make maintaining climate change awareness among the public even more difficult. One way in which the space agencies are trying to counteract this is with education apps like ESA's Climate From Space iPad app, which puts over 30 years of data at your fingertips with interactive globes and maps. NASA also has a series of apps designed to spread the climate change message, including Images of Change, which shows before-and-after images of global climate phenomena. Aside from ensuring ongoing awareness, another major challenge for climate experts is funding.

"We are working with ESA and the European Commission to try and get a successor to the CryoSat mission, which we rely heavily on," said Shepherd. "This is particularly important to us because it's the only satellite designed to look at the polar regions. It flies really close to the poles while all the other satellites that we've used, fortuitously, see part of the Antarctica and Greenland, but their scope is limited."

The good news is that a major spending bill recently passed by US Congress gives NASA $20.736 billion for 2018, thus restoring a number of Earth-science missions that were targeted for cancellation by the White House, including CLARREO (Climate Absolute Radiance and Refractivity Observatory), which is designed to help detect climate trends and improve climate prediction models. Continued investment across the globe is absolutely essential to keeping climate change at bay. After all, space is our window to the world.

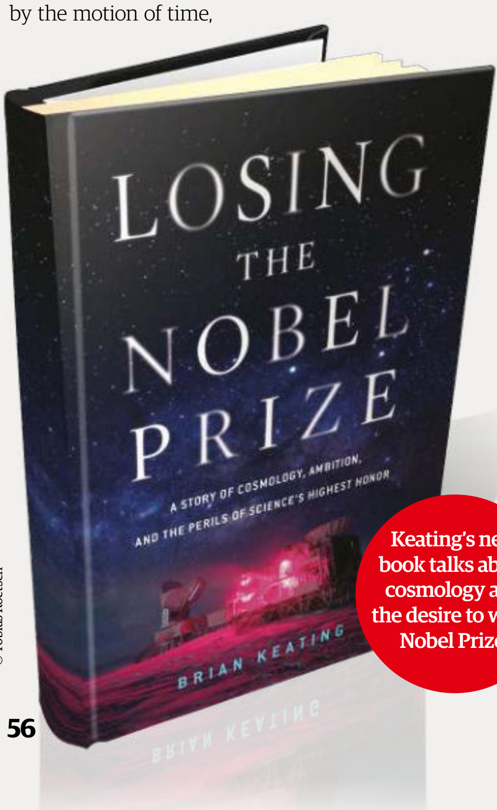
Chasing the Nobel Prize

Brian's journey has led him from the Antarctic to the Atacama Desert. He tells **All About Space** about his pursuit for the answers to the universe's most daunting questions

Interviewed by Lee Cavendish

What led you to focus on studying the origins of the universe and cosmology?
I've always been interested in astronomy since I was about 12 or 13 years old, but I never thought anybody would pay me to be an astronomer. I thought that being an astronomer was like being a wizard and you would have to do it for free. So I never thought I'd be a professional astronomer, and low-and-behold, here I am.

I found astronomy so fascinating, that you could actually quantify, make predictions and understand the behaviour of our universe. But what really spoke to me was that, could you answer the biggest question of them all: how did the universe come into existence? And I was always really fascinated by the motion of time, and why time only seems to go in one direction. You can go left, right, up, down, back and forth [in space], but if time is a dimension like space, then why shouldn't you be able to go backwards in time? That's what drew me to cosmology.



Keating's new book talks about cosmology and the desire to win a Nobel Prize.

© Tobias Roetsch

Why is understanding the universe important?
No one ever wakes up in the morning and says, "I hate the universe. It's so upsetting to me and I wish it would go away."

You have a natural affinity to love learning about the sky. I say that astronomy is the only science, of ancient physical sciences, that you can do with just the two telescopes you have been born with, your eyes. That's really the first connection to any kind of science that human beings have. They see stuff going on in the sky and they want to understand it. I think that's a deep human impulse, that people love and long to know from whence they came. It's part of knowing your past that informs your future, and forms our perspective.

It was these questions that led you down to Antarctica as part of the BICEP2 mission. How was that experience as a whole, living in Antarctica?
Well it's very different to San Diego. You really have to try and imagine a science-fiction world, on an alien planet, that's made of pure ice. Everywhere you look, there's just a frozen expansive whiteness the likes of which I've never encountered before.

The South Pole is nearly completely flat. There are a couple of buildings that were obviously built by human beings, but looking around in all directions it's as if you went into the middle of the ocean and froze it and painted it completely white. You look around and see these buildings built up on stilts, because we need to protect them from getting overrun with snow. The snow doesn't clear itself unless you have your building built up on stilts, so the snow can blow underneath. Just like it's done in many coastal areas of the United States, to not let sand pile up over beachfront real estate, they build their houses up on stilts. They do the same with snow to prevent against snow build up. You see people dressed up almost like astronauts, with their full survival gear, boots that have three centimetre [1.2 inch] thick soles that are vacuum insulated to protect from instantaneously getting frostbite.


Keating suggests that the discovery of a 'multiverse' could be the next big astronomical breakthrough

It's a completely other-worldly landscape, and I was just in such a mixture of emotions when I got to see the place where our experiment is going to spend a decade or more of its life. Your ideas, and those of your colleagues and students, have taken you to this forbidden landscape.

It really sinks in that you're at a really special place where all the time zones of the world are all converging. All of these factors conspired to make the experience of being in the Antarctic very similar to being on a different icy planet, I assume.

Why are the conditions in Antarctica ideal for looking at the Cosmic Microwave Background?

Professor Brian Keating

Brian Keating is professor of physics and astronomy at the University of California San Diego

INTERVIEW BIO

Professor Brian Keating

TED speaker Brian Keating is a professor of physics and astronomy at the University of California, San Diego, the director of the Simons Observatory and author of the recently published book *Losing the Nobel Prize: A Story of Cosmology, Ambition and the Perils of Science's Highest Honor*.

Brian's past work has included extensive studies into the ancient light originating from the start of the universe, known as the 'Cosmic Microwave Background'. His journey to Antarctica to study this light unfortunately led to an incorrect announcement. Understanding the origins of the universe remains his top priority.

The Cosmic Microwave Background [CMB] is made up of photons from the primeval oven that the universe forged the first elements within. So these are the lightest elements, and when they were formed, the left over binding energy of formation was released in a form of heat. That heat propagated throughout the universe for 13.8 billion years, until it arrived at our telescopes. If you've used a microwave oven before, you know that microwaves are efficient absorbers of water, and water is very much present in the Earth's atmosphere.

Often times we would like to go to space. My community has built three satellites, so far, that have been to space to study the CMB, and that's done at great expense and great risk. It's almost 100-times more expensive if we wanted to put BICEP2 in space than the way we built it at the South Pole.

The atmosphere above the South Pole is very space-like – it's very desert-like. There are very few water molecules in the atmosphere above the South Pole. We don't want these photons that are so precious to us, and so few, travelling across the universe, and all of a sudden they smash into a water molecule in our atmosphere. That's no good. So all of our microwave telescopes need to be built at high elevation, in very cold climates or both.

The results that came from the BICEP2 experiment unfortunately weren't what you were expecting. Can you explain what happened?
What happened was the BICEP experiment was seeking a signature from the CMB which, if detected, would reveal the presence of inflation – the so-called 'epoch of ultra-rapid expansion' that immediately followed the Big Bang. In the first trillionth of a trillionth of a trillionth of a second, it's hypothesised that the universe underwent this extremely rapid expansion called inflation. If it did, it would solve a number of problems with the Big Bang theory.

To patch those missing bits, the cosmologists of the 1980s and 1990s created a theory called 'inflation', which ultimately predicted that the microwave background heat would have a twisting, twirling, swirling pattern, in what's known as its 'polarisation'. It became clear to us, and others in the community, that the first people to do this would not only confirm the existence of these waves of gravity that inflation would have caused to resonate in space-time, but also it would be the first pieces of evidence for the quantisation of gravity. This is a goal that eluded even the late, great Albert Einstein and the late, great Stephen Hawking.

How we would do that is complex to describe, but nevertheless the stakes were so high. You could just imagine that something pursued by scientists like Einstein and Hawking is going to be a very, very valuable thing to accomplish. In fact, we were told that the people that could do that would win a Nobel Prize. I think that the impetus for us to pursue this signal was mostly scientific, but there was a part that was caught up in the pursuit of this ultimate accolade that science has to offer, which had been given only twice before in our field. We were going to explain why there was a Big Bang, why there was a universe and perhaps that there is a multiverse. All these things conspired to cause us to want to see this signal.

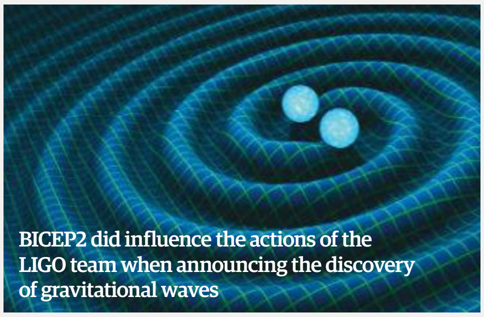
Unfortunately, as with many aspects of science, when you have a hypothesis made by an authority such as Hawking or Einstein, there's a tendency to want to try and confirm the hypothesis rather than dispassionately pursuing all different possibilities, or stumbling upon something serendipitously. We were intent on finding this signal, and I think we did great job in trying to convince we hadn't seen artefacts of the instruments, the atmosphere and our galaxy and Solar System. But we didn't have enough information at the time to rule out the contributions from the contamination of equally tantalising swirls of microwaves from our galaxy.

That was insufficient in terms of ruling out the hypothesis. We detected something much more prosaic, the emission of dust in the microwave band in our galaxy. That's [the discovery] that we now believe we made, but we didn't make a blunder. I always say we didn't leave the lens cap on the telescope, we didn't forget to plug in a fibre optic

"I thought that being an astronomer was like being a wizard and you would have to do it for free"

The BICEP2 experiment studied the Cosmic Microwave Background in amazing clarity

This leftover heat from the ancient universe can reveal some of the most sought-after answers about our existence


BICEP2 did influence the actions of the LIGO team when announcing the discovery of gravitational waves

cable and make a huge blunder. It's the hypothesis, and the claim that we had detected cosmic inflation that was disconfirmed.

Do you think BICEP2 results had much influence on other astronomical announcements since?
Yes. I know for certain it had a tremendous influence on the announcement of the detection of gravitational waves by the LIGO experiment. There's a book called *Gravity's Kiss* [written by Harry Collins], and it describes the inner workings of the LIGO team including emails, correspondences and phone calls – all confidential and redacted information – it's kind of cloak and dagger.

But, what's interesting is that they mention BICEP2 dozens of times in their deliberations. Both how to complete the analysis in a way that was dispassionate and agnostic as to the origin of the signal, and also on how to publicise their results.

We [the BICEP2 team] had our press conference the day we made the announcement of the detection of these inflationary gravitational waves but, in the end, our publication was not accepted and peer reviewed until many months after the announcement. So a lot of people took us to task for that. LIGO on the other hand waited until their discovery had been vetted and peer reviewed, and published in physical review letters.

Then there is the EDGES experiment, which is a recent experiment [that detected a signal from a star existing just 180 million years after the Big Bang]. They also had this [the BICEP2 results] in mind, and that they did not want to publish their claims until they had been vetted and peer reviewed and published in an actual journal.

So I know for certain that the BICEP2 episode has become sort of a cautionary tale in some sense, and I think that's one of the lasting pieces of impact of our experiment. I think the way you release your data has a big impact, the medium is the message as they say, and other groups are learning from our experience.

What do you think will be the next big discovery about the universe?
Well, there are just so many mysteries about the universe. I think some of the things that appeal to me are related – unsurprisingly – to my research.

One is what are the properties of energy and matter throughout the universe? So there's a particle called a 'neutrino', which is one of the 17 elementary particles. They are the fundamental building blocks that cannot be divided into smaller units. We don't know how much neutrinos weigh,


It's hypothesised that after the Big Bang the universe underwent rapid expansion called 'inflation'

and that's of great interest to not only cosmologists like me, but particle physicists. You need massive clusters of galaxies to contain the girth that is necessary to have enough of these neutrinos in one place. We hope to do that by using another tool that Einstein invented, called 'gravitational lensing'. That will be literally refracting the signature of the polarisation in the microwave background, this time at small angular scales.

But what I think is the most interesting question is whether or not we are not only not the centre of our galaxy, or Solar System, but also whether or not our universe is the centre of a 'multiverse'. There has been a lot of debate about this most recently by many scientific luminaries, and this debate has been really raging and heating up. It really centres on the Copernican principal, as I discuss in my book; can it be extended beyond our universe? Are we just another universe, just like we're another star or another planet or another galaxy? I think that would be the most fascinating question of all to answer.

Are these the subjects that you are currently studying in the dry conditions of the Atacama Desert in Chile?
Yes, exactly. So I'm the director of what's known as the Simons Observatory, which is a collaboration of over 200 researchers over all seven continents on Earth. It involves the construction of a large telescope, a six-metre diameter telescope that is roughly 20-times bigger than BICEP, and also many, many BICEP-sized telescopes.

So an array of small telescopes, each the size of BICEP, will look for the gravitational wave signature hypothesised, which originated from the Big Bang inflationary epoch. The very large telescope will look for the gravitational lensing effect that would be indicative not only of the mass of the neutrino, but whether there are other particles even more ghostly present.

This is another alien landscape that is actually more reminiscent of a volcanic planet like Mars where there are these enormous mountains and active volcanoes. It's quite an astounding location to be in, you have wear an oxygen tank on your back at all times because you're above half the Earth's atmospheric pressure that you'd feel at sea level. So you're wearing protective clothing such as boots, helmets and then you have cannulas in your nose, pumping oxygen into you so that you can actually have some semblance to sanity at high altitude. It's very difficult, but a very beautiful place to work.

You seem to favour the more extreme working locations, don't you?
[Laughs] That's what I get for living in San Diego, you have to work in these forbidden places!

Boarding soon... Your flight into Space

The commercial space industry is gaining speed, and it could change all of our lives

Written by Ian Evenden

Once, space launches were the preserve of national governments, as the USA and USSR tussled over who had the biggest rockets. Even Britain got in on the act, with the Black Arrow rocket, launched from Australia, and placing a single satellite into orbit.

Black Arrow was canned for the same reason a lot of space ventures fail – costs. In 1966, NASA received some 4.41 per cent of the US federal budget, but in 2017 its share was only 0.47 per cent, and it hasn't been over 1 per cent since 1993. This reluctance on the part of governments to fund space exploration has seen collaboration between countries that led to the International Space Station, and the rise of the private space launch company.

There are some big players in this field, headed by billionaires such as Elon Musk and Jeff Bezos, while the Russian Space Agency is quite happy to exchange tens of millions of dollars for a trip into orbit. These ventures, with their camera-pleasing technology, tend to hog the limelight, but there's a lot more to the commercial space industry, and figures from Bryce Space and Technology show that, in 2017, $2.5 billion was invested in commercial space start-ups by venture capital firms. There's also a huge market for the data gathered by spacecraft, particularly those looking down on the Earth.

As plans for spaceports are put forward all over the world, spaceplanes – reusable vehicles that can take off and land like a regular airplane, but also operate in the airless zone at the top of our atmosphere – are a popular idea. Far from flying out for a quick jaunt around the Moon while sipping an agreeable pinot noir served by a handsome steward, these early tourism flights are likely to be suborbital, not reaching high enough to enter orbit, but going much, much higher than any commercial aircraft and experiencing weightlessness for a few minutes at the top of their curving flightpath.

Space tourism company Starchaser Industries has a different plan, however. It is working towards the launch of a reusable rocket ship with space for three passengers. "We have a rocket called Nova 2. It's a 12-metre rocket with a one-person capsule on the end," says Starchaser CEO Steve Bennett. "We've done some manned tests with the capsule – we threw it out the back of a plane at quite a high altitude – and the person on board deployed a steerable parachute and brought the capsule back down safely. We've done that a few times, and the next stage is to launch the capsule on a rocket." Bennett has previous experience in this area, as Starchaser holds the record for the biggest successful rocket launch over the UK mainland.

"We're going to launch Nova 2 with a crash test dummy on board, not a real human," Bennett continues, "but if that works then we're very close to actually launching people."

This isn't going to happen in the skies over Britain, though. "We have a site in New Mexico where they've built the spaceport," says Bennett, referring to Spaceport America in the United States. "We've got 20 acres of land and will build a facility there for assembling and servicing our rockets. The idea is to launch all the way to space from there."

Spaceport America also houses the spaceplanes of Virgin Galactic, whose SpaceShipTwo is carried to high altitudes by its White Knight Two launch vehicle before igniting its rocket engine to climb into the upper atmosphere for a suborbital flight. Following the crash of the first SpaceShipTwo, VSS Enterprise, in 2014, its successor, VSS Unity, is currently undergoing flight testing.

Elsewhere in America, the political landscape is shifting in favour of commercial spaceflight.

"If space launch vehicles were being launched routinely, the cost of access to space would come right down" **Steve Bennett**

Starchaser CEO Steve Bennett with the Nova 2 capsule that can carry a person to the edge of space on a rocket

Proposed spaceports

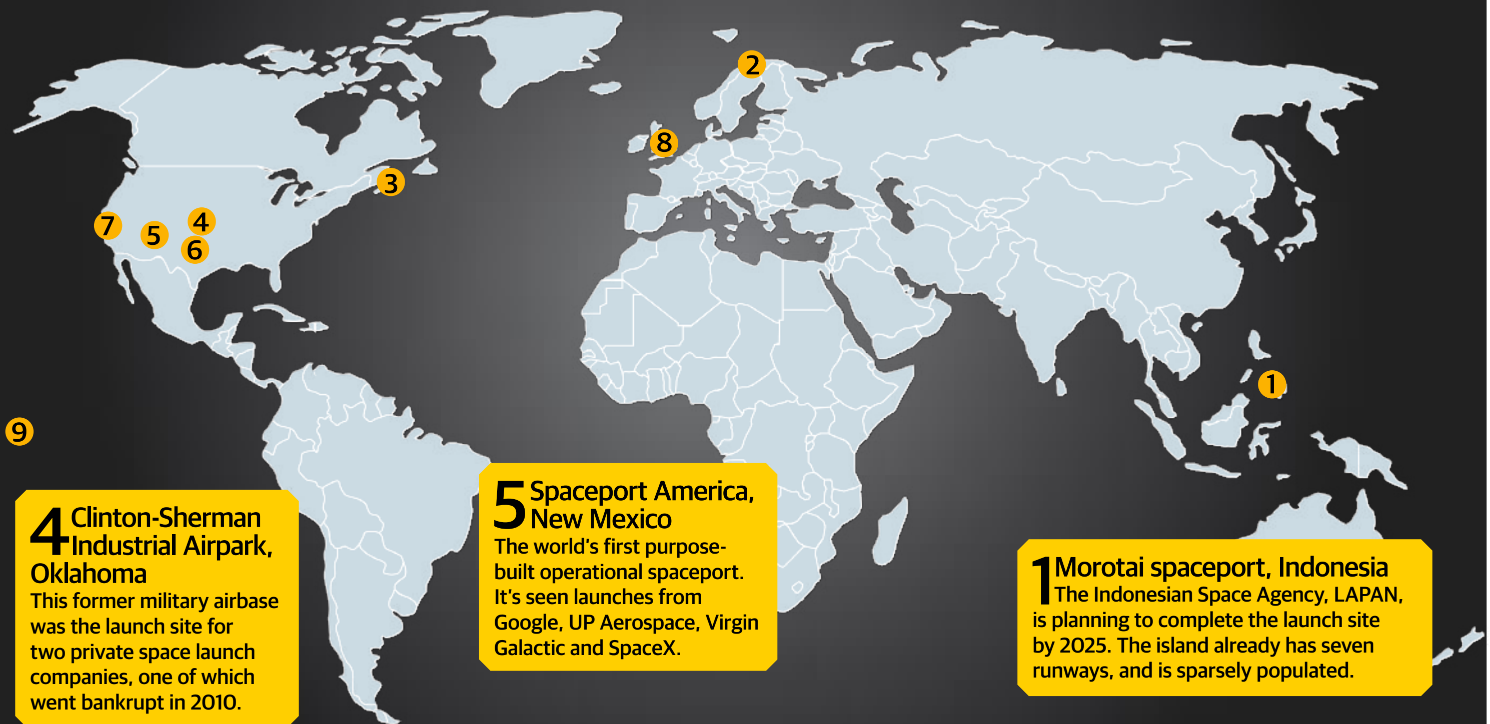
If you're going to fly, you need somewhere to take off from

7 Mojave Air and Space Port, California
Mojave is home to more than 60 companies, including Virgin Galactic, the Orbital Sciences Corporation and The Spaceship Company. It's also a storage location for commercial airliners.

3 Canso, Nova Scotia
Maritime Launch Services, a joint venture between three US companies, aims to launch eight Ukrainian-built Cyclone-4M rockets every year by 2022.

8 Britain... somewhere
Six locations for a British spaceport were shortlisted in 2015. The government now supports building one at any 'suitable' location.

2 Spaceport Sweden, Kiruna
An agreement with Virgin Galactic was signed in 2007 for operational SpaceShipTwo flights, but none have yet taken place.



4 Clinton-Sherman Industrial Airpark, Oklahoma
This former military airbase was the launch site for two private space launch companies, one of which went bankrupt in 2010.

5 Spaceport America, New Mexico
The world's first purpose-built operational spaceport. It's seen launches from Google, UP Aerospace, Virgin Galactic and SpaceX.

1 Morotai spaceport, Indonesia
The Indonesian Space Agency, LAPAN, is planning to complete the launch site by 2025. The island already has seven runways, and is sparsely populated.

9 Sea Launch
Sea Launch has put over 30 rocket payloads into geostationary transfer orbit. Being mobile, rockets can be fired from the optimum spot to reduce costs.

6 SpaceX South Texas Launch Site, Texas
SpaceX's home base is due to be completed no earlier than 2019, and features a space tracking facility along with launchpads for Falcon 9 and Falcon Heavy rockets.

Departures

Destination	Date
Morotai spaceport, Indonesia	Before 2040
Spaceport Sweden, Kiruna	Departing
Canso, Nova Scotia	2022
Clinton-Sherman Industrial Airpark, Oklahoma	Unlikely
Spaceport America, New Mexico	Departing
SpaceX South Texas Launch Site, Texas	Departing
Mojave Air and Space Port, California	Departing
British spaceport	Site not selected
Sea Launch	Departing

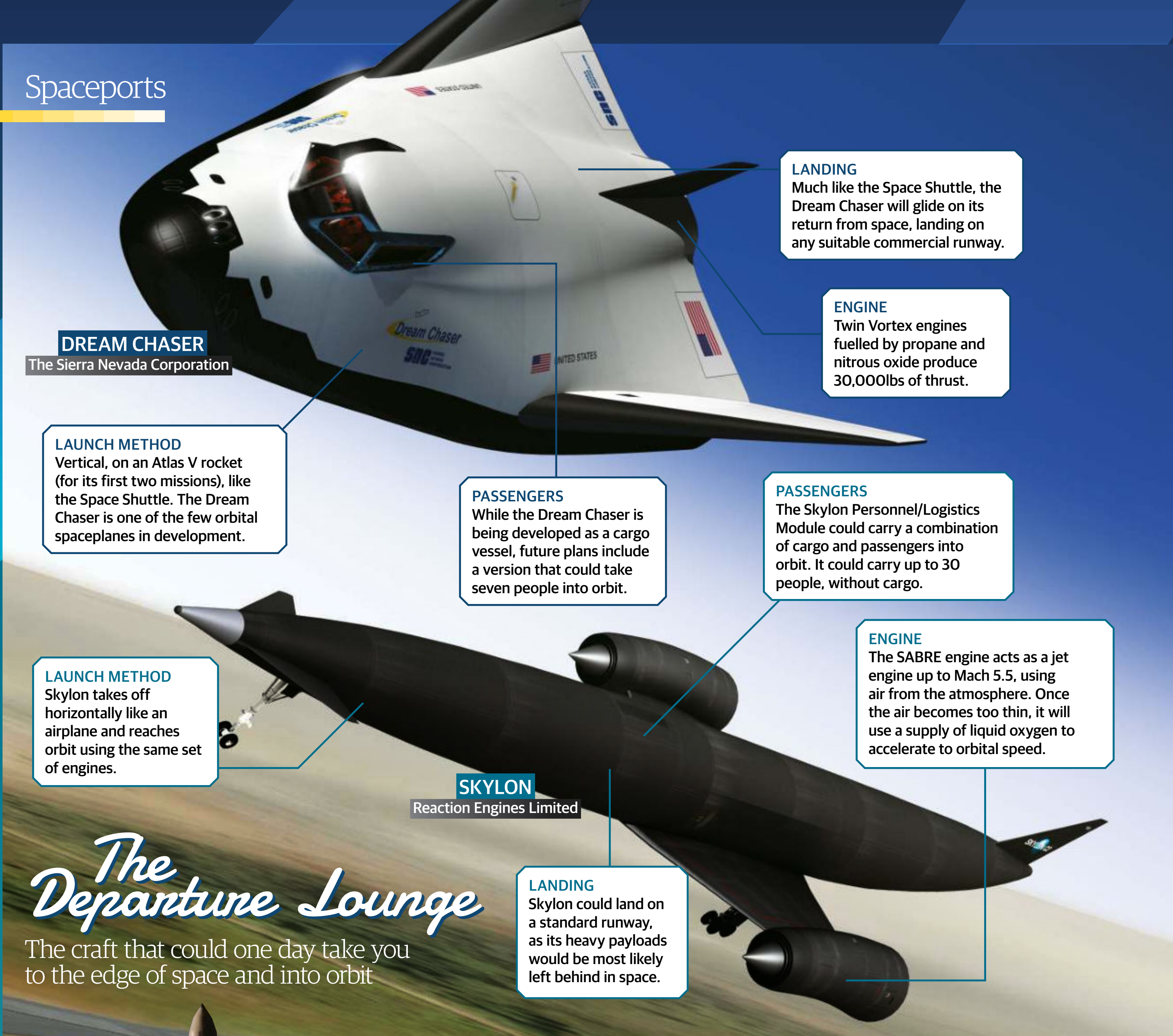
President Trump, speaking at the beginning of March, praised SpaceX and Elon Musk for the successful launch of the Falcon Heavy rocket, noting that: "They said it cost $80 million. If the government did it, the same thing would have cost probably 40 or 50-times that amount of money."

Another billionaire with his sights set on the stars is Jeff Bezos, CEO of Amazon. His company, Blue Origin, favours a rocket-based capsule launch rather than a spaceplane, and crewed tests of the New Shepard 3 vehicle are expected later this year. The company has its own spaceport, the Corn Ranch in western Texas, operational since 2006.

You don't have to be a billionaire to consider launching tourists into space, however, as much it may help. Starchaser's Bennett was once a lab technician who built rockets in his spare time, while Reaction Engines, a company founded in 1989 by three former Rolls Royce rocket engineers, is working on hypersonic passenger aircraft as well as its own space tourism project - the Skylon spacecraft and SABRE engine. Developed from the HOTOL - a cancelled 1980s spaceplane design - and the RB545 engine concept, Reaction Engines' single-stage hybrid jet/rocket engine technology could carry 24 passengers to orbit, or 11 tonnes of

The Departure Lounge

The craft that could one day take you to the edge of space and into orbit




Starchaser's Nova 1 rocket taking off. It still holds the UK record for the biggest successful rocket launch ever fired from the British mainland

> "You could travel from London to Sydney in 45 minutes if you did it as a suborbital flight" **Steve Bennet**

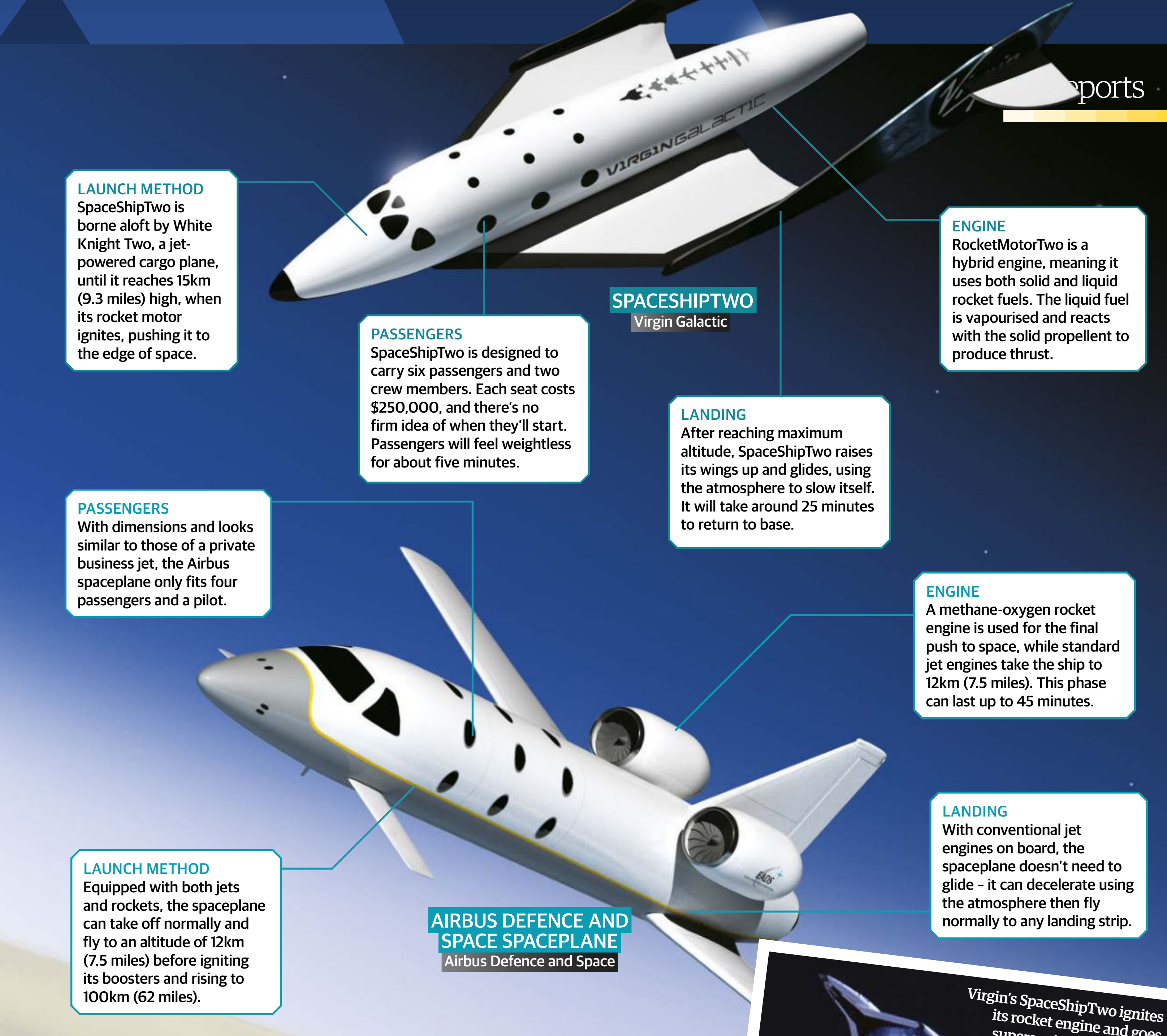
cargo to the International Space Station, 45 per cent more than the ESA's Automated Transfer Vehicle.

In Britain, the Space Industry Act 2018 received royal assent in March and paves the way for launches into space from UK soil as well as modernising UK law to keep up with the rapid commercialisation of the space industry, which averaged a 6.5 per cent growth rate over the last decade and employs 35,000 people across the country.

The location of a British spaceport is yet to be confirmed, however, with the government supporting the creation of one at a 'suitable' location, but failing to suggest where that location might be.

Britain isn't brilliantly placed for rocket launches – they tend to be carried out near the equator, as this gives you an extra speed boost thanks to the spin of the Earth, and from an easterly coast to fly over the sea with the rotation of the planet. The position of the Kennedy Space Center on America's east coast means rockets fly out over the ocean. A rocket launch site in Essex would send its payloads over Europe, with potentially disastrous consequences in the event of a crash.

A British spaceport is more likely to support spaceplanes than rockets, but launches are not the only way a private company can get in on the space tourism action. The need for deep-space tracking and communications will grow as the number of launches increases, and while at the moment this is carried out by NASA's Deep Space Network and the



European Space Agency, the private sector has now got a foot in the door.

Goonhilly Satellite Earth Station in Cornwall got its first dish in 1962 to link with communications satellite Telstar. This grew to over 60 dishes, and it was once the world's largest satellite Earth station. Thanks to an £8.4 million investment, Goonhilly is to be upgraded to become the world's first commercial deep-space communications site, and will start by tracking the ESA's Mars Express, which has been orbiting the Red Planet since 2003.

And it's not just Cornwall that's seeing investment in commercial space science. Next to the National Space Centre in Leicester, a Space Park is being built with £12.87 million of government funding to combine Leicester University teaching and research with commercial propositions, aiming to develop cutting-edge satellite technology, and analyse the data the satellites send back.

"We expect to have people like Airbus and Lockheed in there," says Professor Martin Barstow, professor of astrophysics and space science at the University of Leicester and director of the Leicester


Virgin's SpaceShipTwo ignites its rocket engine and goes supersonic during testing


Spaceport America, in the Jornada del Muerto desert, is the world's first purpose-built commercial spaceport

The flight experience

A sub-orbital flight is similar to a normal plane journey, but with extra rockets

1 Launch
The carrier aircraft takes off like a normal plane, but when it fires its rocket at an altitude of 15km (9.3 miles) it will fly straight up, and 3.5-times the Earth's gravity will press you into your seat.

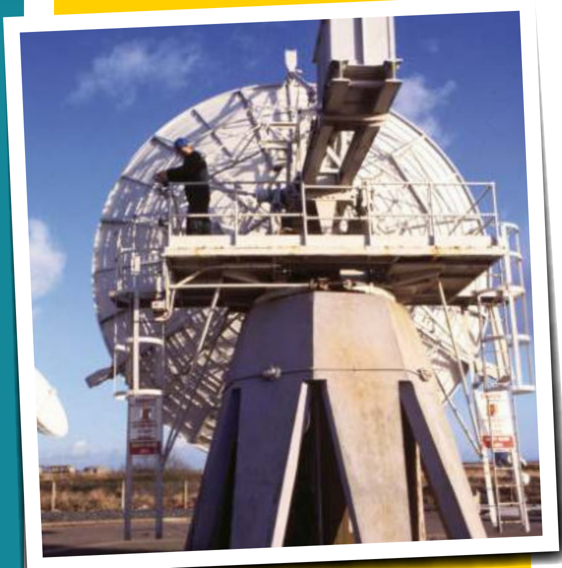
2 Weightlessness
On a suborbital flight there will be around six minutes when the engines are off. During this time, the tourists experience weightlessness.

3 Return
Comfortable deceleration from 4,000kph (2,500mph) to a safe landing speed could take some time, so don't expect the return trip to be quick.

4 Brace yourself!
Space travel is physically demanding. On a longer flight, expect dizziness and nausea for the first 24 hours as your body adjusts.

5 Will I need a passport?
Probably not, as suborbital flights take off and land at the same spaceport, so you're technically not crossing any borders.

PASS



Dish number one at the Goonhilly Earth Station, Cornwall, colloquially known as 'Arthur'

Institute of Space and Earth Observation. "What we're doing is engaging with larger companies, and a lot of small companies, about what their needs are, and co-designing the facilities with them.

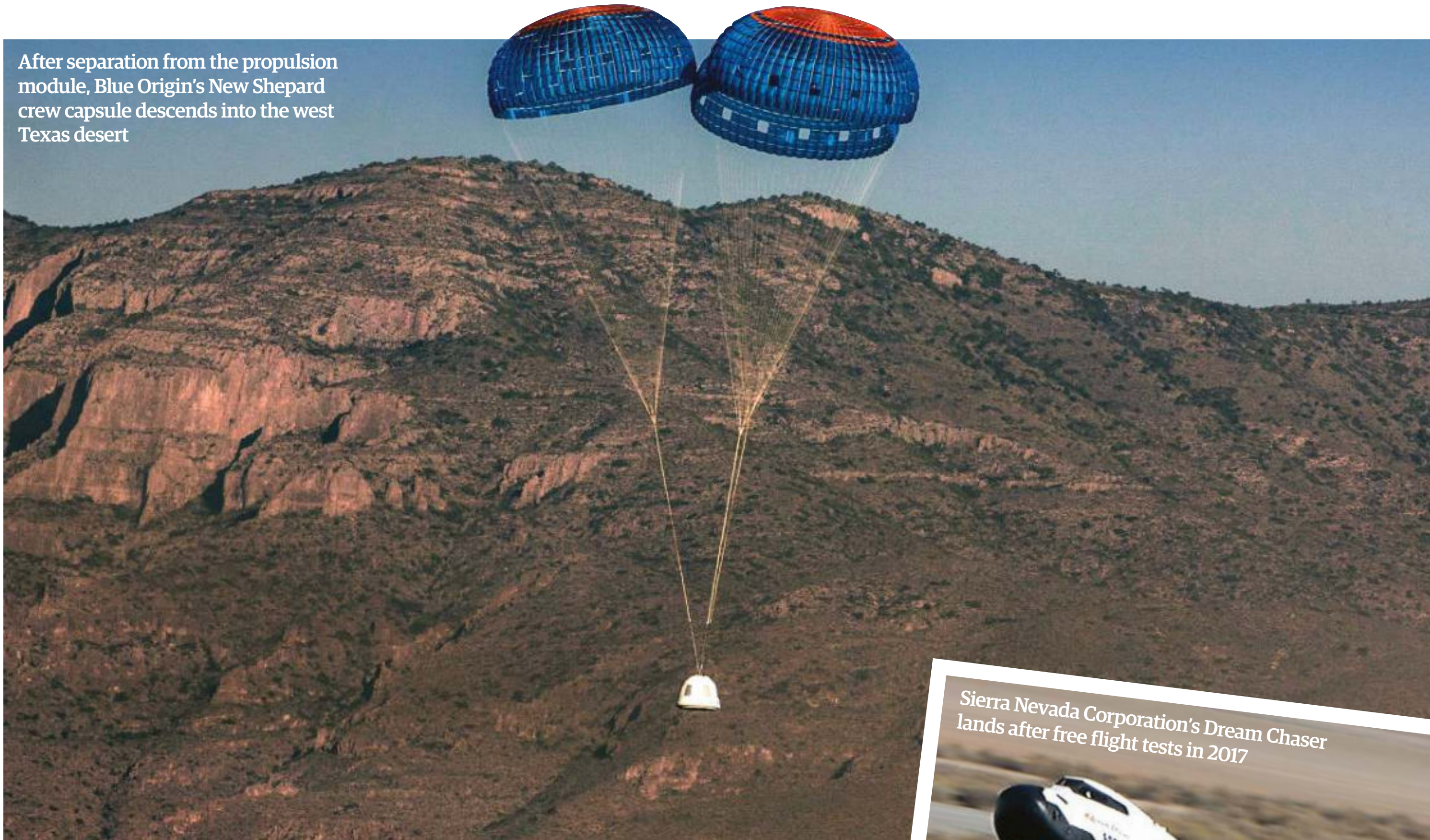
"We won't be launching from Leicester, it's not well located," he continues, "but we expect the park to be producing payloads, medium-sized satellites built in large numbers to service the new demands for Earth observation data, and for it to supply the pipeline for any new launch services that are located in the UK, as well as further afield. Our Earth observation expertise in particular is fundamental to understanding where the growth opportunities are around applications of space data, which is predicted to be the largest potential growth market from space in this country."

Space data is exactly what the Goonhilly project is hoping to capitalise on too, and Barstow explains that companies investing in such schemes may not be traditional 'space companies'. "Many companies might want access to data, such as agricultural technology companies using Earth observation data," he says. "Some of it may be around what we call situational awareness – monitoring of disasters or undesirable things like fires, particularly in tracts of pristine forest, or active deforestation by people. You can use space data to improve the way people deal with these things."

In this way, private space launches and data gathering are building on the foundations laid by national governments over the last 70 years. There's still an enormous role for state-sponsored launches, however; they literally help get things off the ground. "Getting stuff into space is very expensive," says Starchaser's Bennett. "If space launch vehicles were being launched routinely – daily – the cost of access to space would come right down. Space tourism is going to help drive the costs down because there are a lot of people who'd like to go. So with a mass market, the price would really come down and space would really open up."

Barstow agrees. "Governments have an important role [in space exploration] because sometimes things are very high risk, at a level that often private enterprises can't really deal with," he says. "Everybody talks about people like Elon Musk, and

> "Governments have an important role [in space exploration] because sometimes things are very high risk" **Prof Martin Barstow**



After separation from the propulsion module, Blue Origin's New Shepard crew capsule descends into the west Texas desert

Sierra Nevada Corporation's Dream Chaser lands after free flight tests in 2017

Space Park Leicester is the UK's first national space park

others who are doing great work in the US. Those private companies wouldn't have been able to do that without an awful lot of government contracts along the way to get them running. And the very deliberate policy within NASA to put the contracts out to private companies instead of building in-house in a way that de-risks the process for the company has been extremely successful. I hope we would do something similar in the UK."

Bennett anticipates one more advantage to a newly privatised space future: "It's going to transform the way we live on Earth," he says. "You could travel from London to Sydney in 45 minutes if you did it as a suborbital flight. Once you get into space, you're halfway to anywhere – the Moon is full of resources, the Sun is brighter in space so solar panels become more efficient. If you could set up solar panels in space and beam the energy back to Earth that would be a very green way of generating electricity."

Whether we end up with banks of orbiting solar panels or not, private spaceflight is here to stay, and while space tourism may look like a scheme to separate rich people from their money, it plays an important role in getting other things, such as Earth observation satellites or those solar arrays, off the ground… and it could change our lives significantly.

TIPS & TRICKS FROM THE EXPERTS

How you can make a new discovery

The night sky is an ever-changing canvas - and you don't have to be a professional to spot a difference and make an astronomical finding

Space is a limitless cauldron of unknown quantities of asteroids, comets, planets, stars and other such objects. This is a thought that is as daunting as it is exciting, and the fact we never know how many objects are actually out there means there is always a chance to discover something new.

Even just within our Solar System astronomers continue to see new comets and asteroids. Scientists have estimated there could be potentially trillions of comets and asteroids in the Solar System, reaching as far as the Oort Cloud beyond the orbit of our farthest planet Neptune. Yet it doesn't stop there. There is so much more beyond our Solar System, including an huge number of stars on the brink of exploding as a supernova. For the ones that haven't exploded yet, there is the high possibility for discovering new exoplanets.

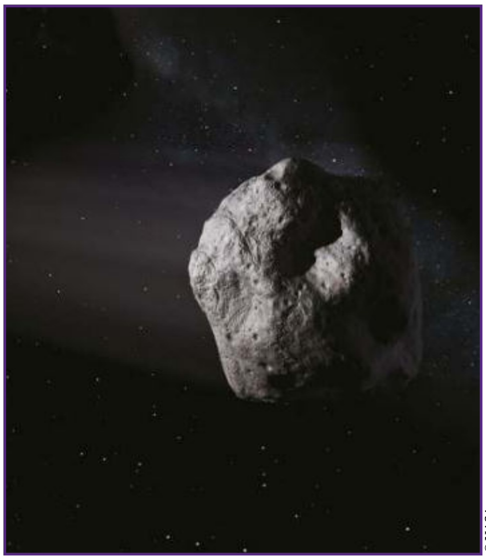
With astronomical equipment being constantly improved and available at a more affordable price, there's never been a better time to start observing the universe then now. Not just that, but there are several citizen science projects that you can do from the comfort of your home. With a medley of secret objects and new innovative mediums for discovery, amateur astronomers can still make a meaningful contribution to astronomy. These stories and tutorials of how other amateur astronomers made their discoveries can serve as inspiration that anybody can discover a new celestial object on any given night.

Gary's tutorial: discover an asteroid

Gary Hug

From Scranton, Kanas, United States, Gary is a retired machinist with 45 years' experience as an amateur astronomer. He is an active member of the Northeast Kansas Amateur Astronomers League and has been hunting asteroids since the year 1997.

Send your report to
minorplanetcenter.net/iau/mpc



© NASA

1 Collecting the equipment

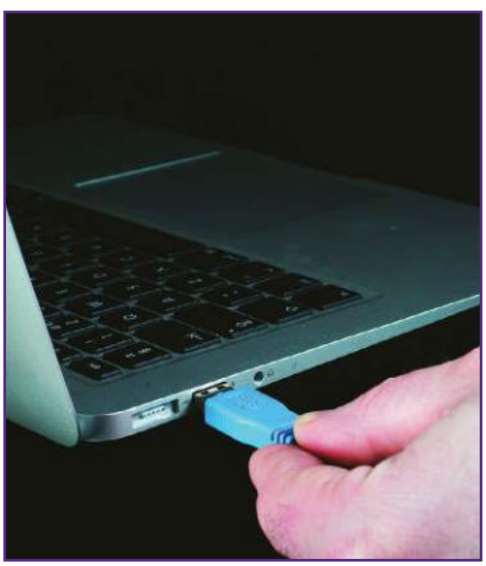
Some very large asteroids are bright enough to be seen with a pair of binoculars, so even a modest-sized telescope can be used to observe them. With a decent CCD camera capable of a long exposure time, and a 20-centimetre [8-inch] driven telescope, one can image asteroids down to about 18th or 19th magnitude.

2 The art of preparation

About halfway between sunset and total dark, I take some images called 'flat fields' in order to record any anomalies in the optical path, such as dust, and to normalise the imaging. I also take dark images by completely covering the imaging chip to measure the thermal noise so it can be subtracted back out.

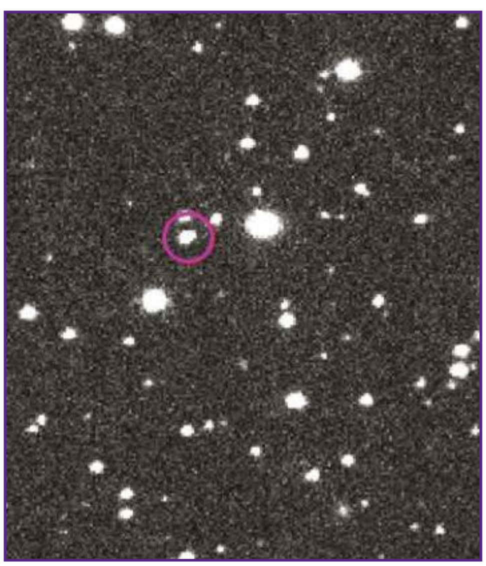
3 Playing the field of view

If I'm hunting for main belt asteroids, I shoot in a position that is nearly opposite to the Sun along the ecliptic. Main belt asteroids are brightest generally at that point in the sky. Near-Earth objects, on the other hand, are all over the sky. It is best to try and do your work when they're higher up (45 degrees or higher above the horizon is best).



4 Take plenty of images

If I'm shooting an object that is travelling fast I may be restricted to 15 or 20 seconds per image, and in that case I can take hundreds of images on that target. With other slower objects, I may shoot a dozen images and that will be enough. On average I shoot 300 to 500 images a night. It is better to take too many than too few.



5 Identifying the culprit

One finds asteroids by their movement against the background stars. To do this I take a few images stretched across 20 to 30 minutes. I load up two sets of images with the recorded time separation then alternately display each set – called blinking. If something has moved it will appear to jump back and forth as the images switch.

6 Confirming the discovery

I check with the Minor Planet Center's (MPC) database to see if there is a known asteroid. If not, I'll follow the object for about half an hour and turn the data into the MPC. If it's an interesting object I may try to image it for another couple of nights, and with positions on three nights, I can calculate an orbit using a program called 'Find Orb'.

Named after its discoverer Edmond Halley, Halley's Comet was first observed in 1758

"Discovering a comet requires a lot of luck and determination"

Fred Bruenjes

Fred is the co-owner and chief engineer at DayStar Filters. He has been an amateur astronomer since 1986 when Halley's Comet passed through, which sparked his desire to pursue astronomy as a hobby. This inspiration led him to the discovery of Comet C/2012 C2 (Bruenjes) in 2009. He is based in Warrensburg, Missouri, United States.

How did you end up discovering Comet C/2012 C2 (Bruenjes)?
For decades I had wanted to discover my own comet, but it took a combination of finally having the time, money, real estate and equipment before it became reasonable to perform a systematic search.

I used a 0.35-metre (14-inch) f/2 telescope and camera with a wide field of view (three by two degrees), a modified mount to slew faster and a custom software application to search parts of the sky that were optimal for locating a comet but hadn't been checked by the professionals within the past month. Once the system had been assembled, I ran it as often as the clouds and Moon would allow.

Was it luck or determination (or both) that led to the discovery of this comet?
There was both luck and determination; as an engineer I computed coverages, probabilities and optimised my equipment and search strategy to give me the best chance of finding a comet.

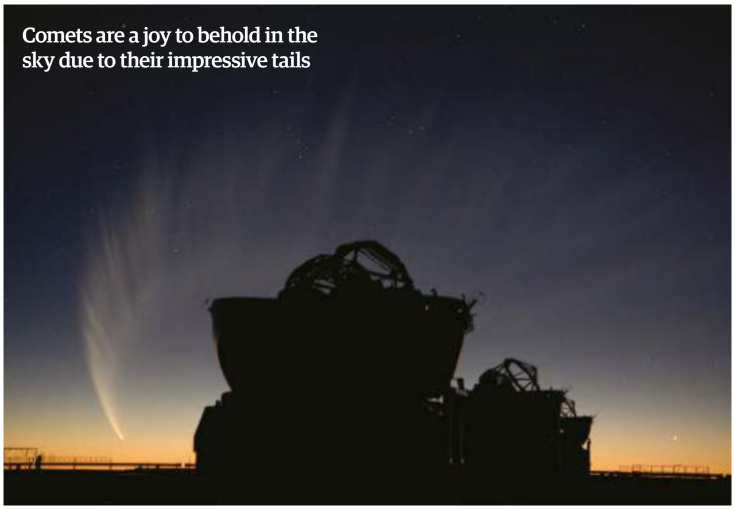
It took years to assemble the gear. Once the search program began, it was only about 76 hours of telescope time before I found a small comet in outburst that no one else had noticed, even though it was quite close to the Earth.

I consider myself extremely lucky to have found a comet in that short of an amount of time; most amateur comet hunters wait many hundreds or even thousands of hours for a discovery.

What advice would you have for anyone trying to discover a comet or any other NEO?
With large-aperture professional surveys vacuuming up discoveries, you need to obtain the largest aperture telescope you can afford, the widest field of view and then look in the cracks between and around their normal search areas.

Their search strategies and observation logs are freely available on the internet and can be used to identify areas of the sky that are being missed in their regular surveys. The alternative is to check mainstream parts of the sky very frequently to try to beat the professionals to a discovery they would make anyway a few days later, but that doesn't feel like a worthwhile scientific contribution to me.

Fred's equipment was carefully assembled to discover a comet



Comets are a joy to behold in the sky due to their impressive tails

Robert's tutorial: Seek a new supernova

Robert Evans

Australia-based Robert is an experienced amateur astronomer as well as a former minister of the Uniting Church in Australia, retiring in 1998. Robert currently holds the record for the most discoveries of supernovae made visually, which total 42 discoveries.

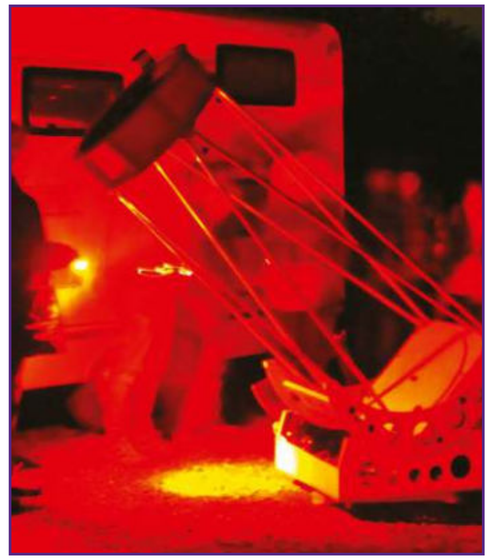
Send your report to
wis-tns.weizmann.ac.il

1 Setting up the telescope

I did my searching visually with a 40-centimetre (16-inch) backyard telescope, simply observing through the eyepiece. The benefit of observing supernovae visually for those interested in science, and in a hobby, is seeing something special and fleeting. It is the same as doing amateur astronomy.

2 Knowing what you're looking for

Before a night's observing, you must know which galaxies you are going to search, and have good reference photos for each. There are websites which tell you where supernovae have been found recently, and you can tell whether they are bright enough or not for you to see through your telescope.



3 Seperating from light pollution

Any amateur astronomer knows which part of the sky is available on any night, or any hour of the night. Also, you have to know how much light pollution has limited the sky where you are living. Obviously faint objects can only be seen from a location where the sky is properly dark and where light pollution is minimal.

© Ilan Shimony

4 Consistent viewing

I tried to observe each galaxy once every week or so. It's possible to discover supernovae visually simply by knowing where the brightest galaxies can be seen. This can be done with a sky atlas, and by looking regularly. If I searched 500 galaxies regularly, I stood a good chance of finding a supernova once or twice a year.

© ESO

5 Noticing the difference

Search each galaxy instantly, spending only a minute on each galaxy. In this case, you can observe as many galaxies as you can in the time you have available. You must be experienced enough so that you recognise any new objects, and follow them up to see what they are. The more you observe, the easier it will be to recognise features.

6 Requesting backup

An experienced observer who avoids making mistakes must verify each suspect, and you must learn how to report any discovery. Make sure you have a friend who knows what to do. Some supernovae are very bright and are obvious to you, while others are very hard to recognise. It is always good to get a second opinion.

Finding exoplanets without leaving the house

Peter Jalowiczor

Peter, who is based in Rotherham, UK, has worked in education since 2011. His primary role is assisting students with learning difficulties. In 2009, Peter also discovered the four exoplanets HD 31253b, HD 218566b, HD 177830c and HD 99492c via the citizen science project called 'The Systemic Project'.

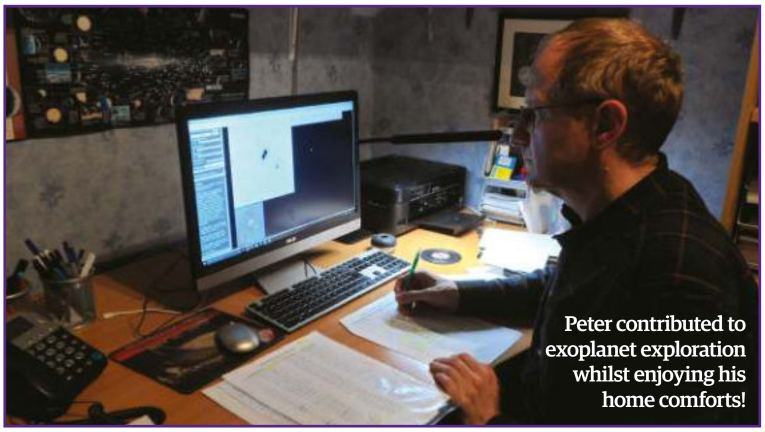
Are you a long-time admirer of astronomy?
My interest in astronomy came at a very early age. I went through all the textbooks at the local library – all pre-Voyager era – this was during the mid-1970s, and many of the books would have been from the 1960s. No flashy images! Analysing the appendices: the outer moons of the Solar System data, I thought what would it be like to visit them. Surface gravities were quoted for the Moon and Mars, but not for the moons. A bit of maths playing around with their masses and their diameters solved this. Many years later in an A-level Physics class I was completely gobsmacked to find that Newton had already covered this!

Can you please explain the project that led to your exoplanet discoveries?
The Systemic Project was a forerunner to many of the citizen science projects today. In 2005, scientists at the University of California, Santa Cruz, United States, set up an international collaborative project for astronomy enthusiasts. Approximately 1,400 members were registered at the peak of the project in 2009. Now it's closed.

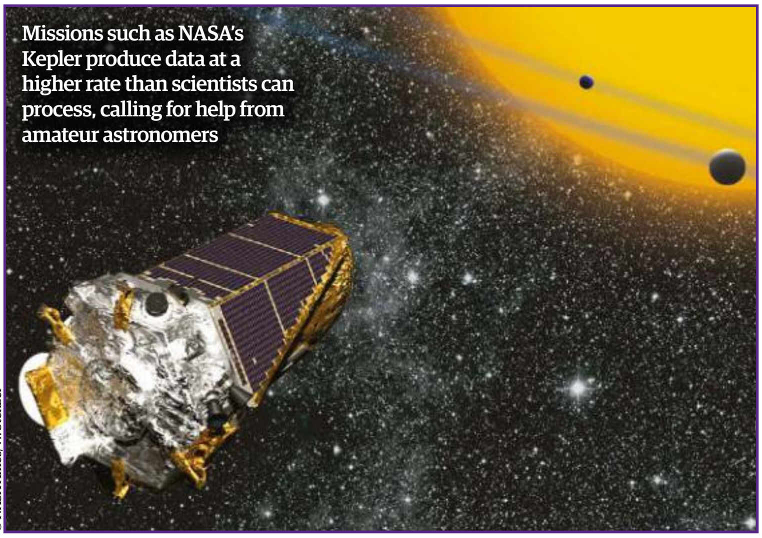
It offered access to real exoplanets radial-velocity data. This technique measures the wobble that an unseen planet induces in the star. It was the most productive detection and characterisation method, until being overtaken in recent years by the transit method. I processed over 1,000 models of systems and gave feedback on the performance on the software, installed on my PC. This turned out to be more important than any detection! Then I was invited as the citizen science representative in the final publication, which listed four exoplanets, all gas giants. The first, HD177830c, was confirmed on Christmas Eve 2009, and of the others HD218566b was the 500th listed.

With exoplanet research becoming more prominent in recent years, do you feel as if amateur astronomers, such as yourself, can still make a significant contribution to the cause?
I feel that amateur astronomers have a lot to contribute to astrophysics projects, and not just in exoplanets projects. If you look at the rise of citizen science projects, particularly the Zooniverse Projects, about 17 are in the space category! Scientists are inundated with data. This means that there is a niche here to take over.

Of course this really depends on how far you wish to take the project. One was registered with over a hundred thousand volunteers, now this number is down to single figures online at any one time. It depends on whether this is just temporary involvement or something for a number of years. This needs a systematic approach. Long-term staying power is the key; an hour or two an evening is ideal (not 20 hours a day followed by burnout!). This is when the expertise develops and the discoveries should start coming in...



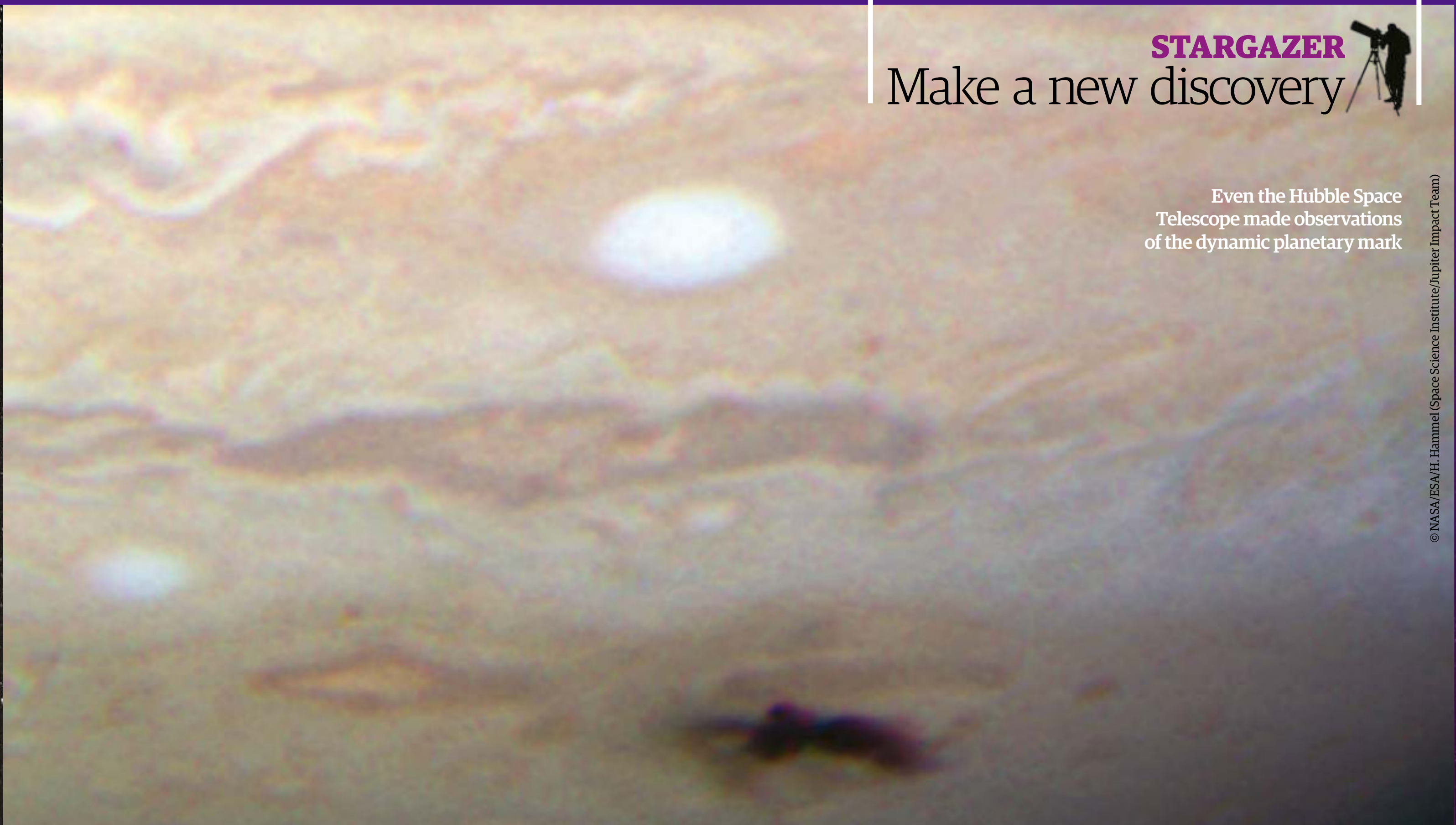
Peter contributed to exoplanet exploration whilst enjoying his home comforts!



Missions such as NASA's Kepler produce data at a higher rate than scientists can process, calling for help from amateur astronomers

© NASA Ames/W. Stenzel

There have been a great number of gas giant exoplanets, similar to Jupiter, discovered throughout the years



Even the Hubble Space Telescope made observations of the dynamic planetary mark

Identifying a scar left on gas giant Jupiter

What were your original intentions the night of the 2009 Jupiter scar discovery?
I was recording images of Jupiter with the Great Red Spot visible on that night. It was a cold winter's night in Murrumateman, and I would take regular breaks from astronomy to go up to the house for a hot drink and to check on the progress of some sport that I follow (cricket and golf, both happening in the UK on the other side of the world).

As it was a Sunday night, I would normally stop around 10pm since I had to work the next day, but this night I decided to continue a bit longer than normal and continue recording video on Jupiter for another couple of hours.

At what point did you realise there was something peculiar, and how did you get the feature confirmed by NASA?
Just after midnight I started noticing a dark spot coming into view on the edge of Jupiter's disc near the south pole. I originally assumed it was a moon shadow, but eventually I realised this was in the wrong place to be a moon shadow. In the final colour image, it was apparent that this was something very abnormal. The image showed a dark spot with what looked like a shock wave spreading out from it.

It seemed more and more likely that I was seeing the after effect of a large impact on Jupiter from some unknown object. I sent an email alert out to my mailing list that contained both amateur astronomers and professionals.

One of the professional astronomers on my mailing list is Dr Glenn Orton from NASA's Jet Propulsion Laboratory, and he had time booked on NASA's Infrared Telescope (IRTF) in Hawaii on the following day, and by a stroke of luck he would see the same part of the planet containing this dark spot.

How do you feel that you that you were the first person to discover a collision on a different planet in the far-away reaches of the Solar System?
It was a very surreal experience - coinciding with both the total solar eclipse in China and also the week of celebrating the 40th anniversary of the Apollo 11 moon landing.

It seems that the public and media were primed for stories about science and astronomy. I spent the following week doing many media interviews and also trying to record more images of the impact site itself - it was changing and evolving rapidly in Jupiter's winds. The impact site was visible for a couple of months before fading away. Another one of the surreal aspects of this discovery was that it was so ephemeral - no permanent mark of any sort was left on the face of Jupiter.

Anthony Wesley

Anthony has worked as a software engineer for most of his adult life. He was interested in all things science when he was younger, including electronics, amateur radio and astronomy. In 2009, Anthony happened to accidently image a scar left on Jupiter's cloud tops, most probably left by a meteor or comet impact.

What's in the sky?

In this issue...

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light

26 APR
Conjunction between Mars and Pluto in Sagittarius

28 APR
The Alpha Scorpiids reach their peak of five meteors per hour

29 APR
Mercury reaches greatest elongation west, shining at magnitude 0.3

4 MAY
Conjunction between the Moon and Saturn in Sagittarius

4 MAY
The Moon and Saturn make a close approach, passing within 1°41' of each other in Sagittarius

6 MAY
The Eta Aquarids reach their peak of 40 meteors per hour

8 MAY
Asteroid 15 Eunomia reaches opposition, glowing at magnitude 9.8 in Centaurus

9 MAY
Comet C/2016 R2 (PANSTARRS) will make its closest approach to the Sun, reaching a magnitude of 11.4 in Auriga

9 MAY
Jupiter reaches opposition, shining brightly at magnitude -2.5 in Libra

13 MAY
The Alpha Scorpiids reach their peak of five meteors per hour


©Damian Peach, Jose J. Chambo

13 MAY
Conjunction between the Moon and Mercury in Pisces

Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of 2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

30 APR
Conjunction between the Moon and Jupiter in Libra

30 APR
The Moon and Jupiter make a close approach, passing within 3°40' of each other

3 MAY
Mercury is at dichotomy, or half phase, shining brightly at magnitude 0.2


©ESA/Hubble & NASA

6 MAY
The Moon and Mars make a close approach, passing within 2°43' of each other in Sagittarius

6 MAY
Conjunction between the Moon and Mars in Sagittarius

11 MAY
Globular cluster Messier 5 (NGC 5904) in Serpens is well placed for observation

11 MAY
Conjunction between Mercury and dwarf planet Eris in Pisces and Cetus

12 MAY
Conjunction between Mercury and Uranus in Pisces and Aries

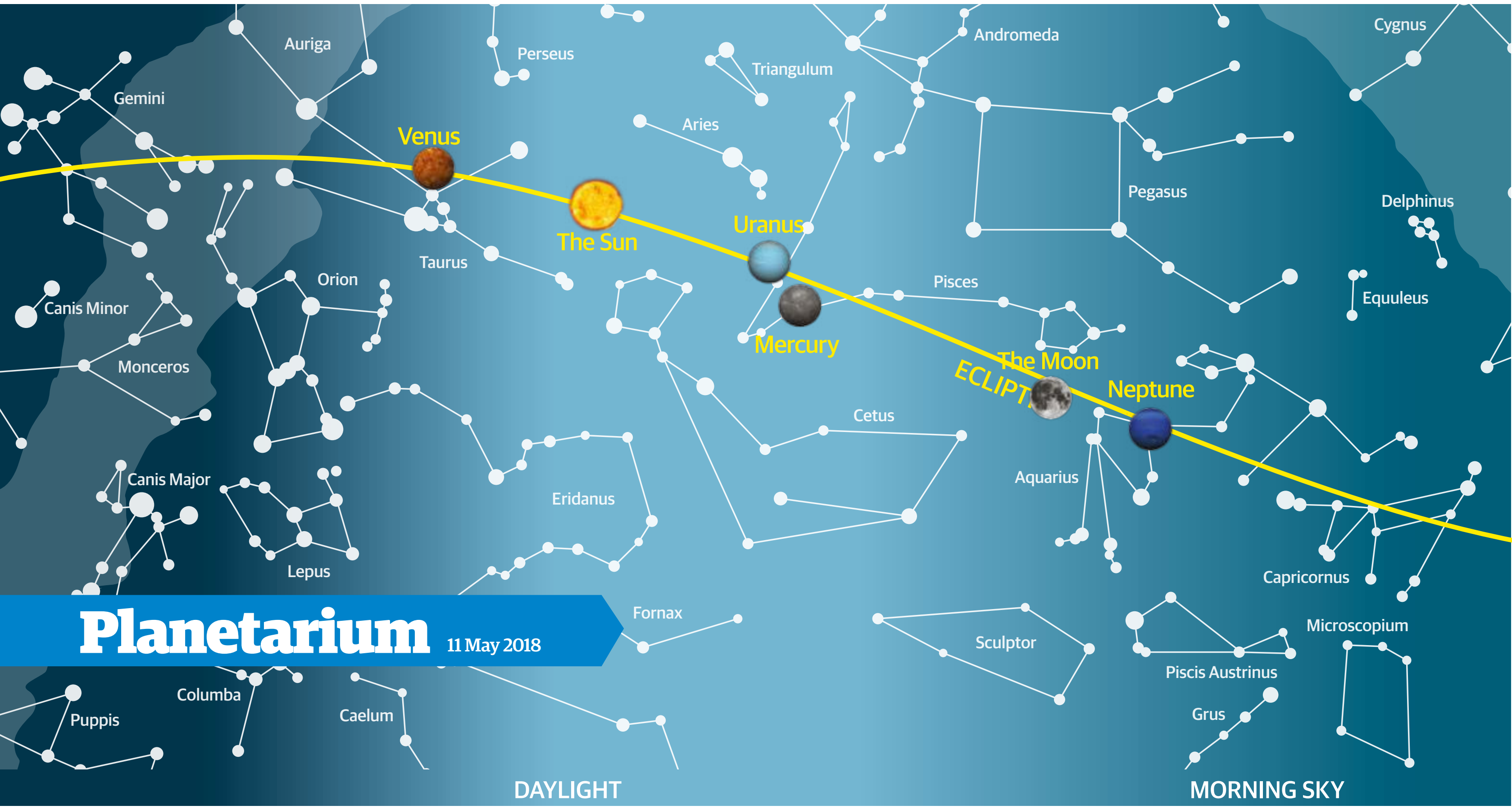
17 MAY
Conjunction between the Moon and Venus in Orion and Taurus

20 MAY
The Moon and the Beehive Cluster (M44) pass within 1°20' of each other

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Planetarium

11 May 2018



Moon calendar

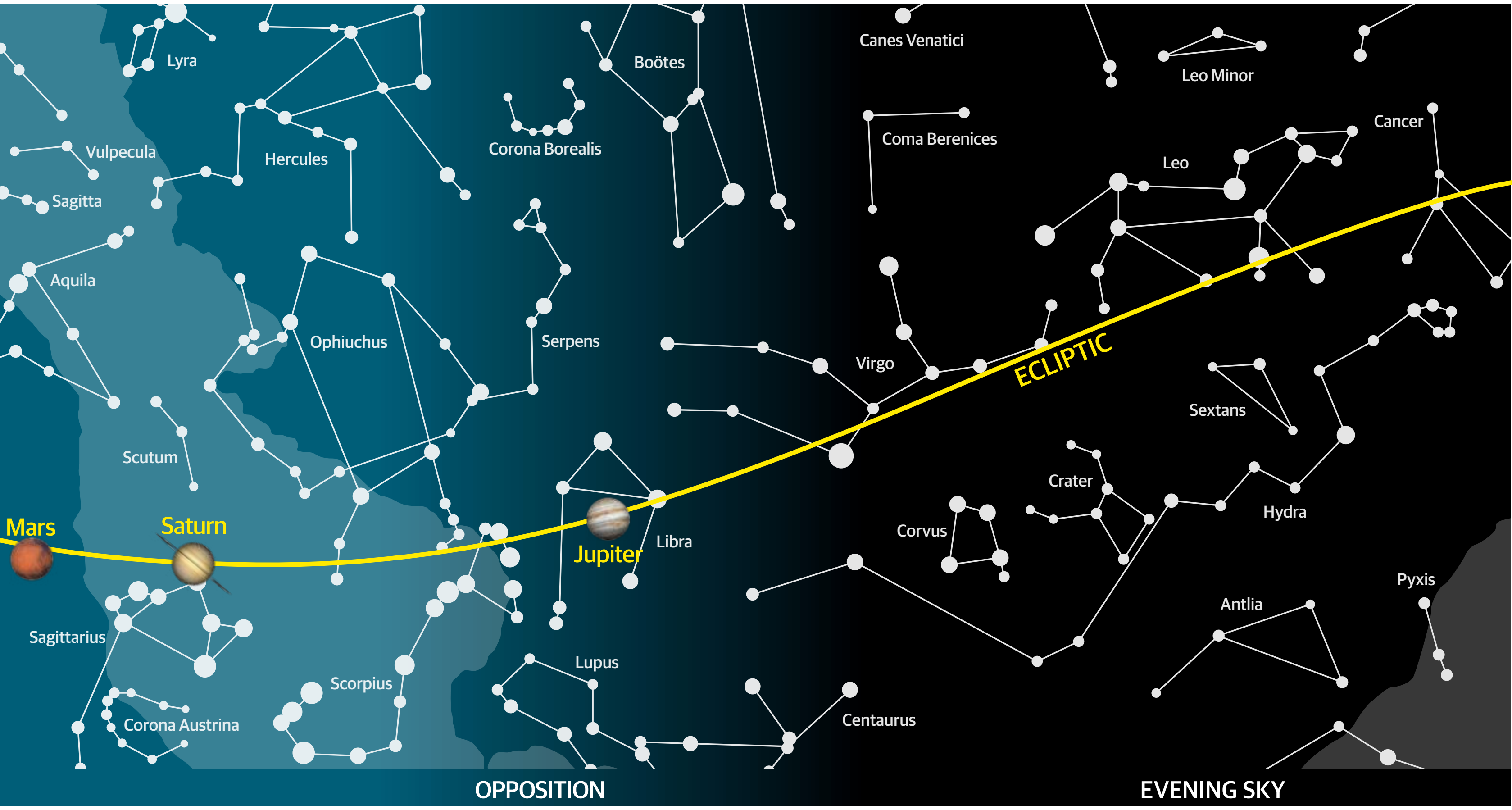
* The Moon does not pass meridian on 28 April

			26 APR 89.0% ▼04:41 ▲21:55	27 APR 95.0%* ▼05:06 ▲22:58	28 APR --:--%* ▼05:29 ▲23:56	29 APR 98.6% ▼05:52 ▲--:--
30 APR FM 99.8% ▼06:16 ▲--:--	1 MAY 98.8% ▼06:43 ▲--:--	2 MAY 95.6% ▼07:14 ▲--:--	3 MAY 90.7% ▼07:50 ▲--:--	4 MAY 84.1% ▼08:31 ▲--:--	5 MAY 76.4% ▲00:48 ▼09:19	6 MAY LQ 67.6% ▲01:33 ▼10:12
7 MAY 58.2% ▲02:11 ▼11:11	8 MAY TQ 48.4% ▲02:43 ▼12:13	9 MAY 38.5% ▲03:11 ▼13:19	10 MAY 28.9% ▲03:36 ▼14:26	11 MAY 19.9% ▲03:59 ▼15:36	12 MAY 12.0% ▲04:22 ▼16:48	13 MAY 5.7% ▲04:45 ▼18:03
14 MAY 1.6% ▲05:10 ▼19:20	15 MAY NM 0.2% ▲05:39 ▼20:39	16 MAY 1.7% ▲06:13 ▼21:56	17 MAY 6.2% ▲06:56 ▼23:08	18 MAY 13.5% ▲07:49 ▼--:--	19 MAY 22.9% ▼00:11 ▲08:51	20 MAY 33.8% ▼01:04 ▲10:02
21 MAY 45.5% ▼01:45 ▲11:17	22 MAY FQ 57.1% ▼02:19 ▲12:33	23 MAY 68.1% ▼02:48 ▲13:49	24 MAY 77.9% ▼03:12 ▲15:02			

% Illumination
▲ Moonrise time
▼ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

	04 MAY	11 MAY	18 MAY	24 MAY
MERCURY	50%	60%	70%	80%
VENUS	90%	90%	80%	80%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	26 Apr	00h 36m 41s	+01° 16' 54"	Cetus	0.5	05:09	17:29
	04 May	01h 06m 32s	+03° 50' 48"	Pisces	0.2	04:54	11:18
	11 May	01h 40m 36s	+07° 21' 06"	Pisces	-0.1	04:43	18:05
	18 May	02h 21m 37s	+11° 39' 27"	Aries	-0.4	04:33	18:41
	24 May	03h 02m 57s	+15° 40' 58"	Aries	-0.8	04:28	19:22
VENUS	26 Apr	03h 56m 20s	+21° 02' 44"	Taurus	-3.9	06:38	22:39
	04 May	04h 37m 19s	+23° 04' 18"	Taurus	-3.9	06:33	23:02
	11 May	05h 13m 50s	+24° 17' 16"	Taurus	-3.9	06:33	23:20
	18 May	05 50m 44s	+24° 56' 41"	Taurus	-4.0	06:38	23:34
	24 May	06h 22m 23s	+25° 02' 51"	Gemini	-4.0	06:45	23:43
MARS	26 Apr	19h 30m 45s	-22° 55' 46"	Sagittarius	-0.3	02:18	10:10
	04 May	19h 47m 02s	-22° 36' 57"	Sagittarius	-0.4	02:01	09:57
	11 May	20h 00m 19s	-22° 30' 22"	Sagittarius	-0.6	01:44	09:45
	18 May	20h 12m 29s	-22° 05' 21"	Sagittarius	-0.8	01:27	09:31
	24 May	20h 21m 55s	-21° 55' 00"	Capricornus	-1.0	01:12	09:18
JUPITER	26 Apr	15h 10m 33s	-16° 26' 11"	Libra	-2.5	21:14	06:32
	04 May	15h 06m 35s	-16° 10' 21"	Libra	-2.5	20:37	05:58
	11 May	15h 03m 01s	-15° 56' 06"	Libra	-2.5	20:04	05:28
	18 May	14h 59m 28s	-15° 41' 57"	Libra	-2.5	19:32	04:58
	24 May	14h 56m 33s	-15° 30' 20"	Libra	-2.5	19:04	04:33
SATURN	26 Apr	18h 38m 15s	-22° 15' 25"	Sagittarius	0.4	01:21	09:22
	04 May	18h 37m 35s	-22° 16' 00"	Sagittarius	0.3	00:49	08:50
	11 May	18h 36m 39s	-22° 16' 00"	Sagittarius	0.3	00:49	08:50
	18 May	18h 35m 25s	-22° 18' 01"	Sagittarius	0.3	23:48	07:53
	24 May	18h 34m 09s	-22° 19' 12"	Sagittarius	0.2	23:23	07:28

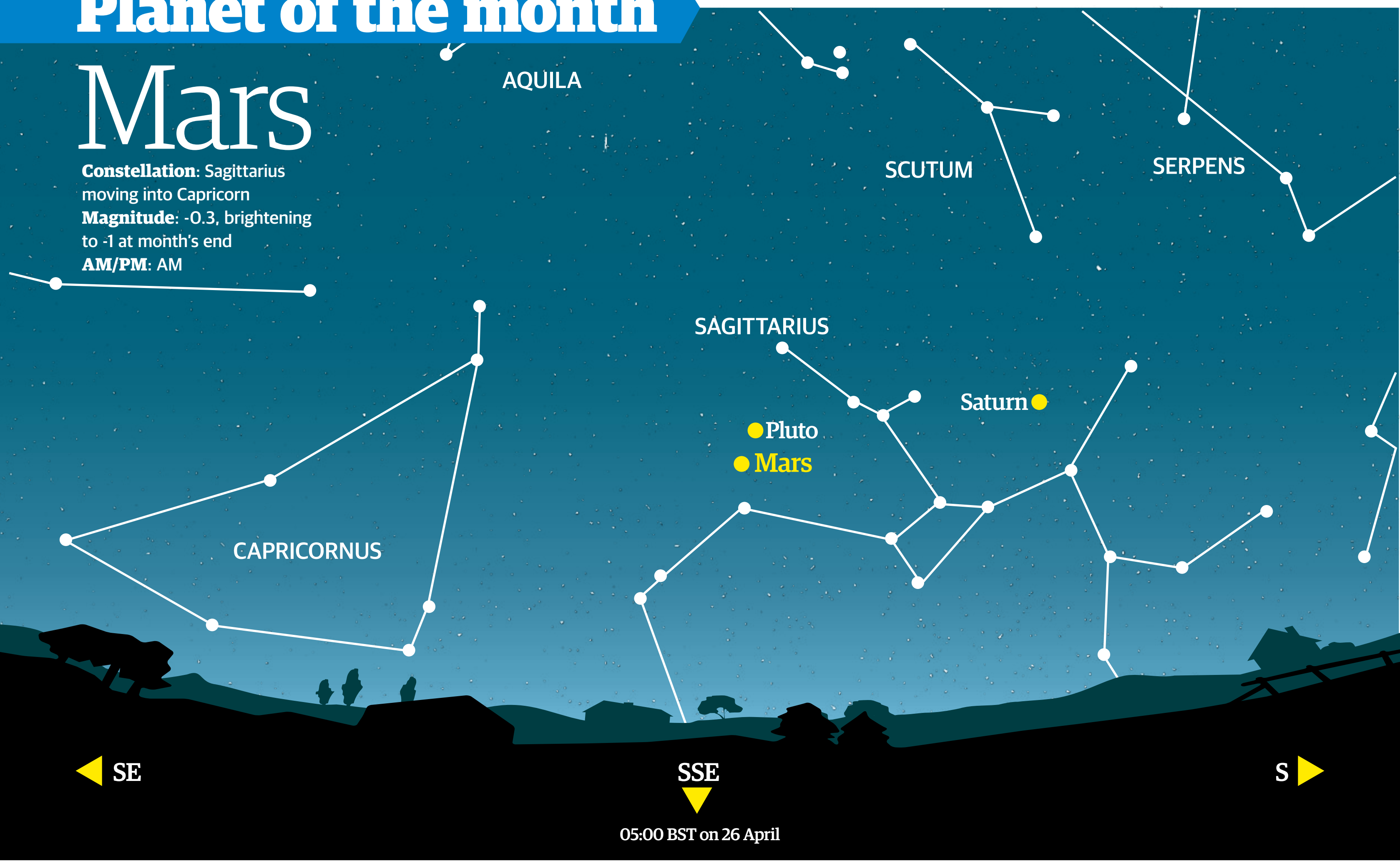
This month's planets

It's the ideal time to observe the Red Planet as it blazes in the morning sky, providing a stunning sight for those early risers

Planet of the month

Mars

Constellation: Sagittarius moving into Capricorn
Magnitude: -0.3, brightening to -1 at month's end
AM/PM: AM



Mars is now really building up for its long-awaited, spectacular summer opposition when it will be a stunning sight in the sky, brighter than it has been for a long time. We'll cover that in full detail then, but this month Mars will get brighter and more obvious to the naked eye with each passing morning.

At the start of our observing period Mars will be rising at around 3am, and by the end of May it will be rising at around half past one in the morning. It will be worth setting your alarm to get up and see it because it will be a lovely sight as it rises in the south east, looking like a distinctly orange 'star' to the lower left of much fainter Saturn.

As if it wasn't interesting enough to look at in its own right, Mars will have a number of close encounters with other celestial objects this month. Between 5 and 7 May the waning Moon will drift past it, and if you have a clear sky on any of those mornings you'll be in for a treat. On the morning of the 5th the Moon will lie 12 degrees to the upper right of Mars, with Saturn just a short distance to the Moon's lower right as an added bonus. The next morning the Moon and Mars will be just two degrees, or four Moon widths apart. By the morning of the 7th the Moon, now at last quarter phase, will be ten degrees above and to the left of Mars.

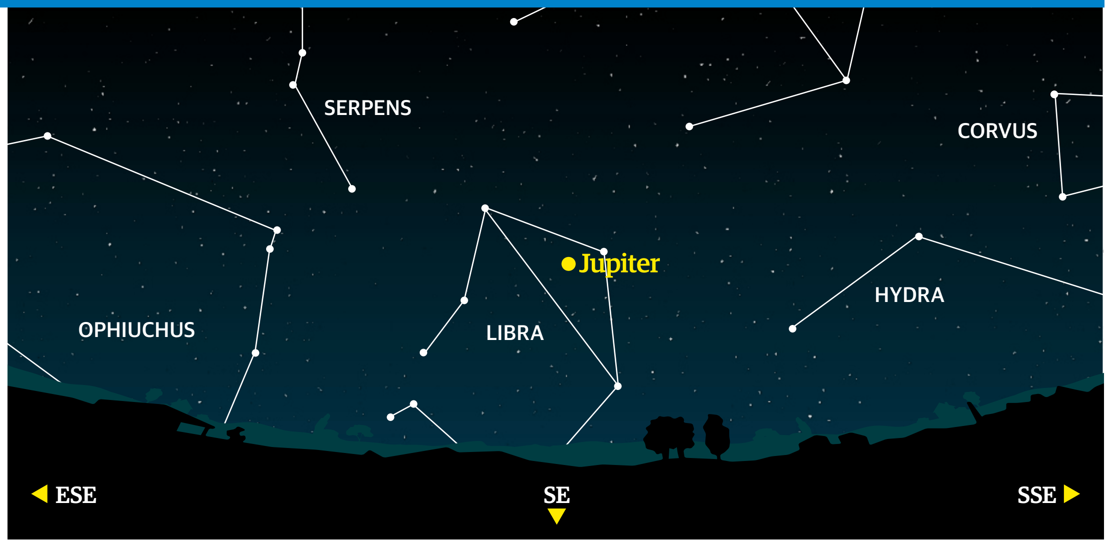
A week later Mars will pass very close to the globular cluster Messier 75. On the morning of 13 May the pair will be half a degree apart. The following morning they will be almost half as far apart as that, just 18 arc minutes between them. Although they'll look very close together, they're a long way apart physically: the cluster is about 68,000 light years away. By the morning of the 15th the pair will be half a degree apart again. On any of these mornings the planet and cluster will look very close together through a small telescope fitted with a low-power eyepiece.

By the end of this observing period, Mars will be shining at a very impressive magnitude of -1, making it appear brighter than every star in the sky, except Sirius. Unfortunately the planet's low elevation above the horizon means we'll have a lot of turbulent and mucky air between it and us, so we won't be seeing it at its best. It will still be immediately obvious to the naked eye, though, and as soon as you look towards the south east you'll see it shining as a bright, orange star. When Mars reaches opposition in late July it will blaze at magnitude -2.8, even though it will still never climb very high above our southern horizon.

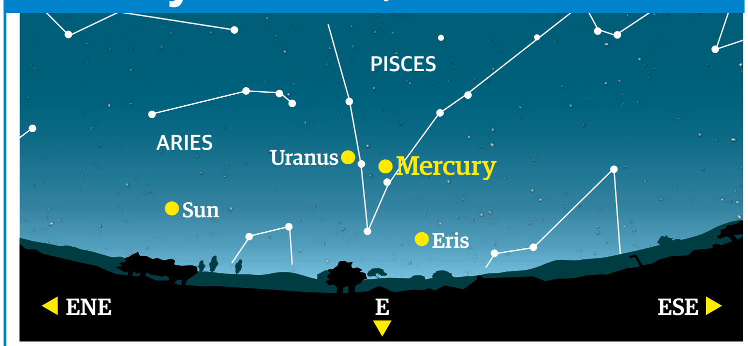
Jupiter 22:00 BST on 09 May

Constellation: Libra
Magnitude: -2.5
AM/PM: PM

If Venus wasn't shining so brightly over in the west, this month's evening sky would belong to Jupiter. Shining at magnitude -2.5 the largest world in our Solar System is brighter than any of the stars in the sky, only outshone by Venus and the Moon. At the start of the month it will be rising around 10pm, and by month's end will be visible low in the east from sunset. On 9 May Jupiter reaches opposition, when it will be a very striking sight in the east after dark. Look for the Moon shining to the planet's upper right after dark on 29 April, and to its lower left on the evening of the 30th. Binoculars will show you the four largest of its family of 69 moons.



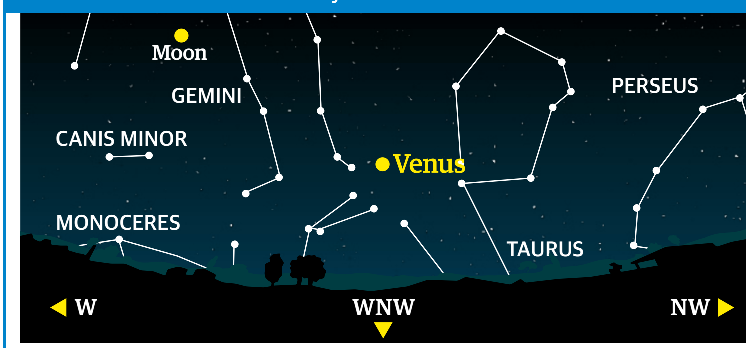
Mercury 06:00 BST on 10 May



Constellation: Pisces
Magnitude: 0.1
AM/PM: AM

This is another very poor month for anyone who wants to see Mercury in the sky. The closest world to the Sun is so close to it in the sky that it rises in the east only a very short time before it. You might get lucky at the end of April if you look really low above the eastern horizon with binoculars before sunrise. By mid-May Mercury will definitely be lost in the bright dawn sky. There will be better opportunities to see Mercury later in the year, so just be patient for now.

Venus 22:00 BST on 10 May



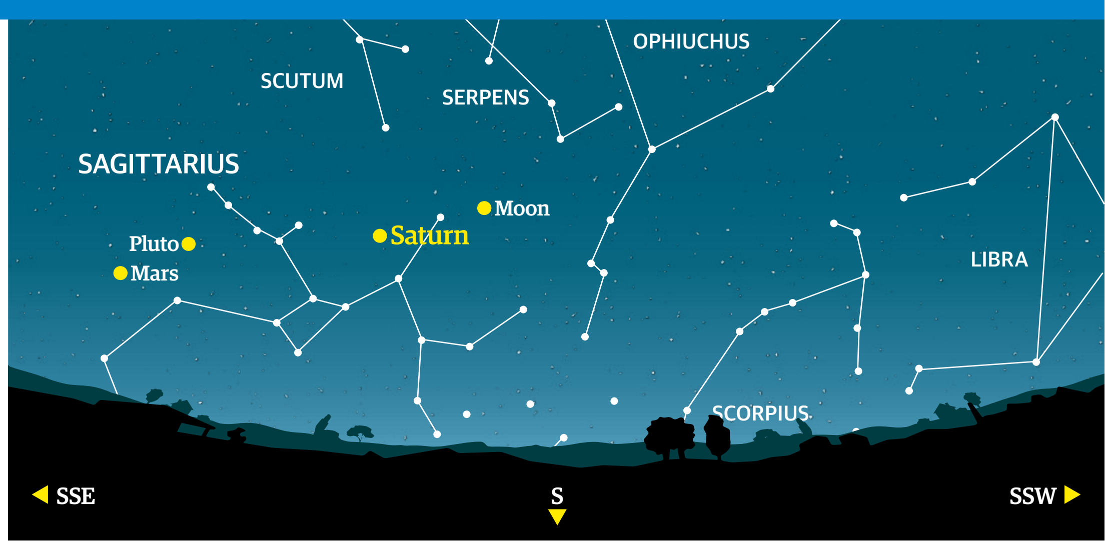
Constellation: Taurus into Gemini
Magnitude: -3.9
AM/PM: PM

Blazing at magnitude -3.9, almost as bright as it can get, Venus will become visible in the west as soon as the sky starts to darken. For over three hours it will be a striking sight, drawing your eye away from everything else. During the month the planet drifts between two large star clusters in Taurus, the famous Pleiades cluster and the V-shaped Hyades cluster. Between 19 to 21 May it will then slide past the much fainter star cluster Messier 35, a very pretty sight in binoculars.

Saturn 04:00 BST on 04 May

Constellation: Sagittarius
Magnitude: 0.4
AM/PM: AM

Saturn doesn't rise above the south eastern horizon until after midnight this month. When it does finally show itself, looking like a gold-hued star shining just above the 'handle' of the famous Teapot of Sagittarius, it will not get very high in the sky. It will trace out a low arc above the southern horizon before the sky becomes too bright before sunrise to see it any more. Before it fades from view it will be an easy naked-eye object. Look for the waning gibbous Moon shining 8 degrees to Saturn's upper right on the morning of 4 May, and just three and a half degrees to the planet's upper left the next morning.



Top tip!

As with all mountains, valleys and craters on the Moon, you'll get your best views of this fascinating feature when it is close to the terminator.

Moon tour

Schiller

Take a look at a fascinating lunar mystery this month...

Everyone loves a good mystery, and astronomy is full to bursting with them. Astronomers are kept awake wondering: What caused the Big Bang? When did Saturn's rings form? Was there ever life on Mars? The Moon has many mysteries too – how exactly was it formed? Will people ever live there permanently? Could it be terraformed to become a second Earth?

However, as puzzling as these questions are, the nature and history of the major features on the Moon's surface are mostly well understood. Thanks to centuries of telescopic study and decades of exploration with space probes and crewed landings, we know how its dark seas and impact craters formed, and why there are far fewer seas on the far side than on the Earth-facing side. But some features on the Moon are more puzzling. Here and there we can see bright debris rays following odd paths away from craters, and even strange, bright swirls on the dark maria. There are also a handful of craters that simply look strange.

One of these is Schiller, a 179 kilometre (111 mile) long, 71 kilometre (41 mile) wide impact feature down in the south, not far from the bright, crater Tycho. Through a small telescope Schiller looks more like a short, stubby valley than a typical round or oval crater. That's partly because being so far south and so close to the Moon's limb we see it at quite an oblique angle, so it appears foreshortened. Overhead views taken during the Apollo missions, or more recently by surveying orbiters, show Schiller really is an elongated feature. It's often described as 'lozenge-shaped' by experienced lunar observers, while others have compared it, rather less kindly, to a leech or a slug!

Look at Schiller closely through a larger telescope using higher magnification on a night when the air is still and you will see quite a lot of detail. You'll see its rim is sharp and well defined, and its walls, which rise some four kilometres (2.4 miles) from its floor, are terraced with various shelves and ledges. There are two low ridges sticking up out of its floor on the western end, but the crater floor on the eastern end is very smooth and flat, with only a couple of craterlets pocking it. When the Sun is hitting Schiller at an angle it really is a fascinating sight, but at full Moon it blends into the background and becomes quite hard to find.

So, where's the great mystery? Well, we're not quite sure how Schiller formed. At first glance, especially at low magnification, it's easy to think that it was made when a single chunk of space debris struck the Moon at a low angle, ploughing a long scar out of its surface. Yet, images taken from above suggest that Schiller is not one, but two craters which formed at the same time, when multiple meteoroids slammed into the Moon almost simultaneously. How many?

Probably a pair, but perhaps as many as four according to some researchers. Schiller isn't unique in this respect; the Orcus Patera crater on Mars looks very similar, and Venus has a crater called 'Graham' which also appears elongated. However it was formed, Schiller is fascinating to look at. So when can you see it this month?

At the start of our observing period the Moon will be almost full, so Schiller will be little more than a bright oval-shaped outline. It should start to pop into view on 8 May, as the terminator begins to sweep towards it. That's when its walls will start to cast shadows, making it stand out from the surface. On this morning the Moon will be in its last quarter phase and low in the sky before dawn, just to the left of the planet Mars. The best time to see Schiller will be between 9 and 11 May, when the Sun's rays will be striking it at a low angle, making it much more obvious. By 12 May the terminator will have rolled over the crater, plunging it into darkness. The crater then won't return into view until after the end of this issue's observing period.

© NASA

This month's naked eye targets

Fascinating stars, clusters and alien worlds are waiting to be seen this month...

TURN TO PAGE 34

The 'Double Double' (Epsilon Lyrae)

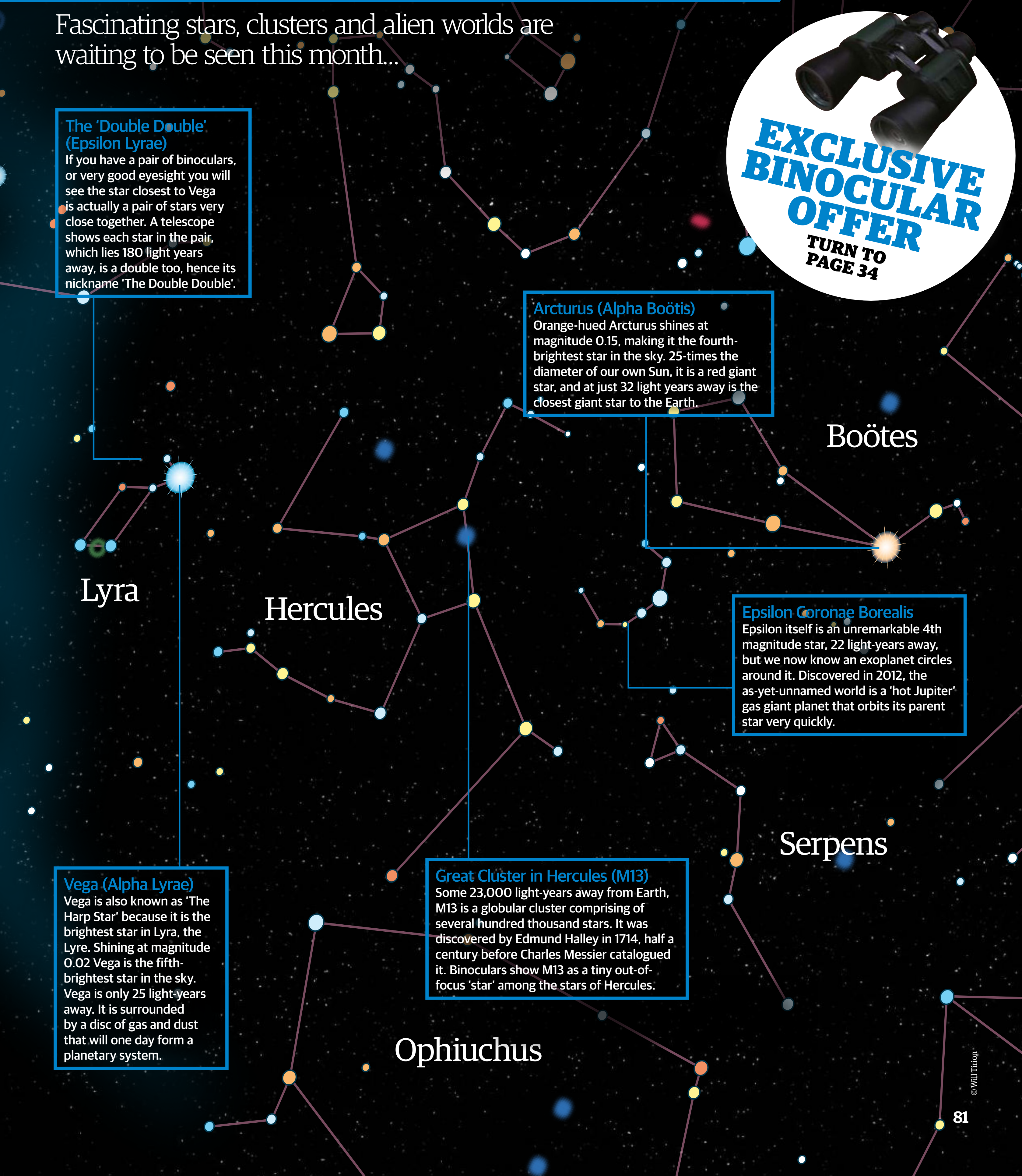
If you have a pair of binoculars, or very good eyesight you will see the star closest to Vega is actually a pair of stars very close together. A telescope shows each star in the pair, which lies 180 light years away, is a double too, hence its nickname 'The Double Double'.

Arcturus (Alpha Boötis)

Orange-hued Arcturus shines at magnitude 0.15, making it the fourth-brightest star in the sky. 25-times the diameter of our own Sun, it is a red giant star, and at just 32 light years away is the closest giant star to the Earth.

Epsilon Coronae Borealis

Epsilon itself is an unremarkable 4th magnitude star, 22 light-years away, but we now know an exoplanet circles around it. Discovered in 2012, the as-yet-unnamed world is a 'hot Jupiter' gas giant planet that orbits its parent star very quickly.



Vega (Alpha Lyrae)

Vega is also known as 'The Harp Star' because it is the brightest star in Lyra, the Lyre. Shining at magnitude 0.02 Vega is the fifth-brightest star in the sky. Vega is only 25 light-years away. It is surrounded by a disc of gas and dust that will one day form a planetary system.

Great Cluster in Hercules (M13)

Some 23,000 light-years away from Earth, M13 is a globular cluster comprising of several hundred thousand stars. It was discovered by Edmund Halley in 1714, half a century before Charles Messier catalogued it. Binoculars show M13 as a tiny out-of-focus 'star' among the stars of Hercules.

STARGAZER

How to...

Find and observe globular clusters

They're among the most fascinating and beautiful objects you can study with a telescope – they're also the most challenging. Here's how to get the perfect view...

You'll need:

- ✔ Star chart
- ✔ Telescope
- ✔ Selection of eyepieces

Globular star clusters contain some of the oldest stars in the known universe. As the name suggests, they are massive balls of stars which can look like a sphere of diamonds through a telescope. Some of them are quite easy to find, although others can be trickier to locate.

Nearly all of the globular clusters we can see with amateur telescopes orbit around our galaxy, the Milky Way, and the ones most easily visible are nearer to our Solar System. How well you can see them depends on how far away they are, the structure of the globular cluster itself and the size of your telescope. Some clusters appear to fill an area of sky, which will make them obvious even in a small telescope at low magnification, whereas others will require a higher power eyepiece and a larger telescope to be seen well.

Globular star clusters can be found almost all year round, but in the northern hemisphere spring is a good time of year, as the Earth's position in its orbit means that we are looking away from the plane of our galaxy and out into deep space, where many such clusters can be seen more easily in slightly less cluttered areas of the night sky.

Although all globular clusters are generally spherical in shape, they all have a slightly different structure. Many are quite compact and appear as tight balls of stars, whereas others have a much looser composition where outer stars in the group are easier to resolve and can have the appearance of being stragglers in the system. Most of these clusters contain upwards of a hundred thousand stars!

It has been found that nearly all of these clusters formed very early on in the evolution of our universe, making them very old. In fact, it is thought that some of these clusters must have formed very soon after the Big Bang itself.

It is well worth taking the time to track down these amazing objects, no matter what size of telescope you have. You will be rewarded with breathtaking views of ancient star systems, which will keep you coming back for more.

> "You will be rewarded with breathtaking views of ancient star systems"

Tips & tricks

Use a star chart
Many of the bright globular star clusters are marked on star charts.

Star hop your way there
One way of locating globular clusters is to 'star hop' to them one field of view at a time, starting from a known bright star.

Choose the right aperture
Usually the larger the telescope, the better – this will help to resolve the stars in the cluster. Small instruments can also provide pleasing views.

Select the right eyepiece
Start with a low-power, wide-field eyepiece to locate the object, then increase the magnification.

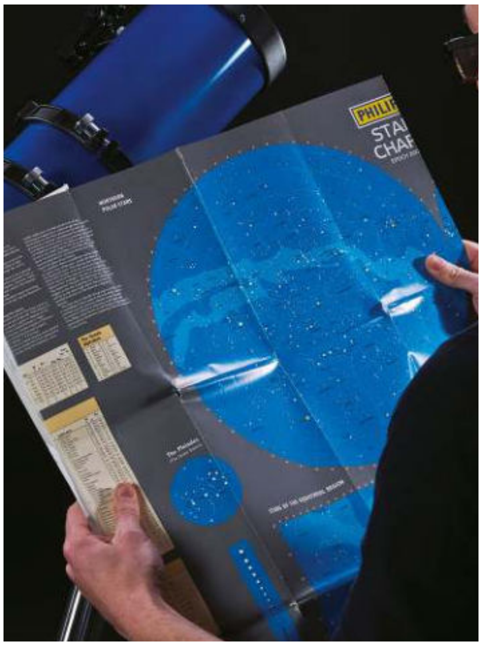
Use averted vision
If you find that a faint cluster is hard to see directly, look away from it about 30 degrees. This should help you spot it.

Create the perfect astro shot

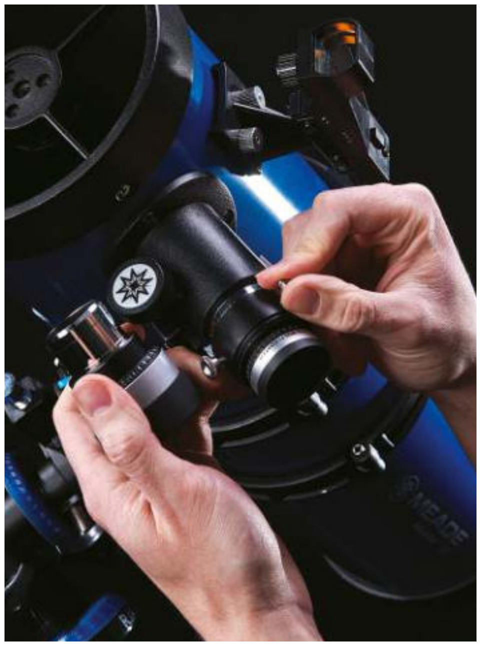
There are many ways of studying globular clusters, including photography...

You will need a tracking equatorial mount and a means of attaching your camera to the telescope. You can use a DSLR camera, or even a smart phone camera on some of the brighter globulars. You will have to vary the exposure time to get the best result depending on the brightness of the particular cluster you are imaging. Increase the ISO value to about 800, but experiment and have fun.

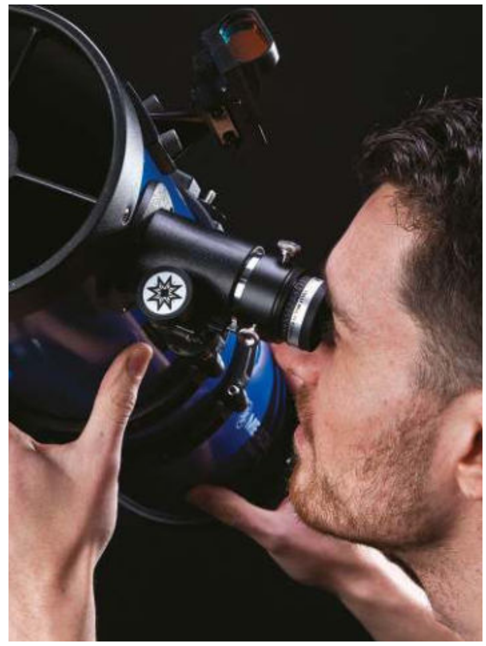
Send your photos to **space@spaceanswers.com**



1 Locate the cluster
Start with a bright cluster such as Messier 5 in Serpens the Serpent. You can star hop to it from the star Alpha Serpentis, also dubbed Unukalhai. Use a star map to work out your starting point.

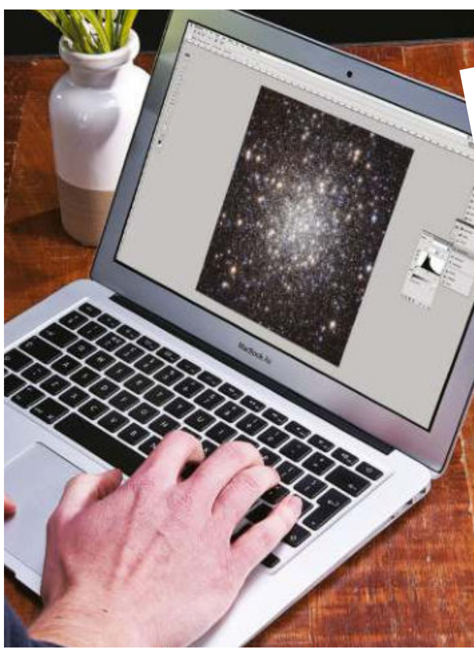


2 Increase the magnification
Once you have centred the cluster in the eyepiece, increase the magnification until it fills the field of view. Don't push the telescope beyond its limit or the view will be blurred.



3 Try and count the stars!
A fun thing to do is to try to work out how many stars you can see in the cluster, or the stellar classification. The stars are so tightly grouped together, so you might have to guess.

4 Grab your DSLR
If you have a digital camera and an adaptor to fix it to your telescope, take several shots with different exposure times. This will help you to get a feel for which settings work and which don't.



5 Use an appropriate editing software
Add the pictures together in Photoshop or similar software to produce an amazing image of the cluster. The software will allow you to pick out colours and create contrast and clarity.

6 Seek other star clusters
There are dozens of other globular star clusters for you to track down and observe, allowing you to truly test your sky-watching and imaging. Good hunting!

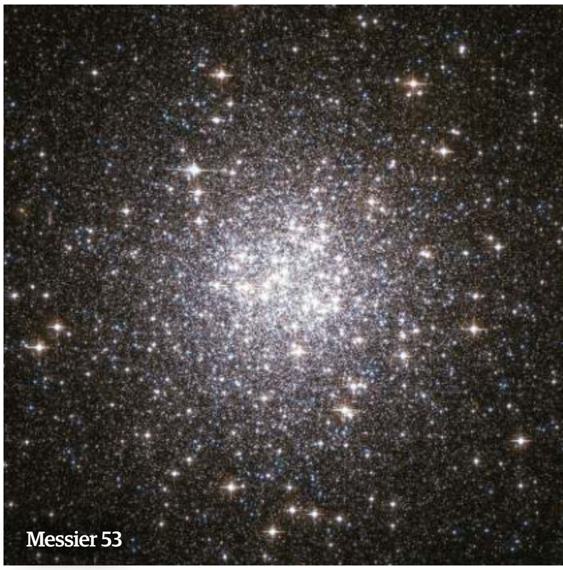
Sombrero Galaxy (M104)

Deep sky challenge

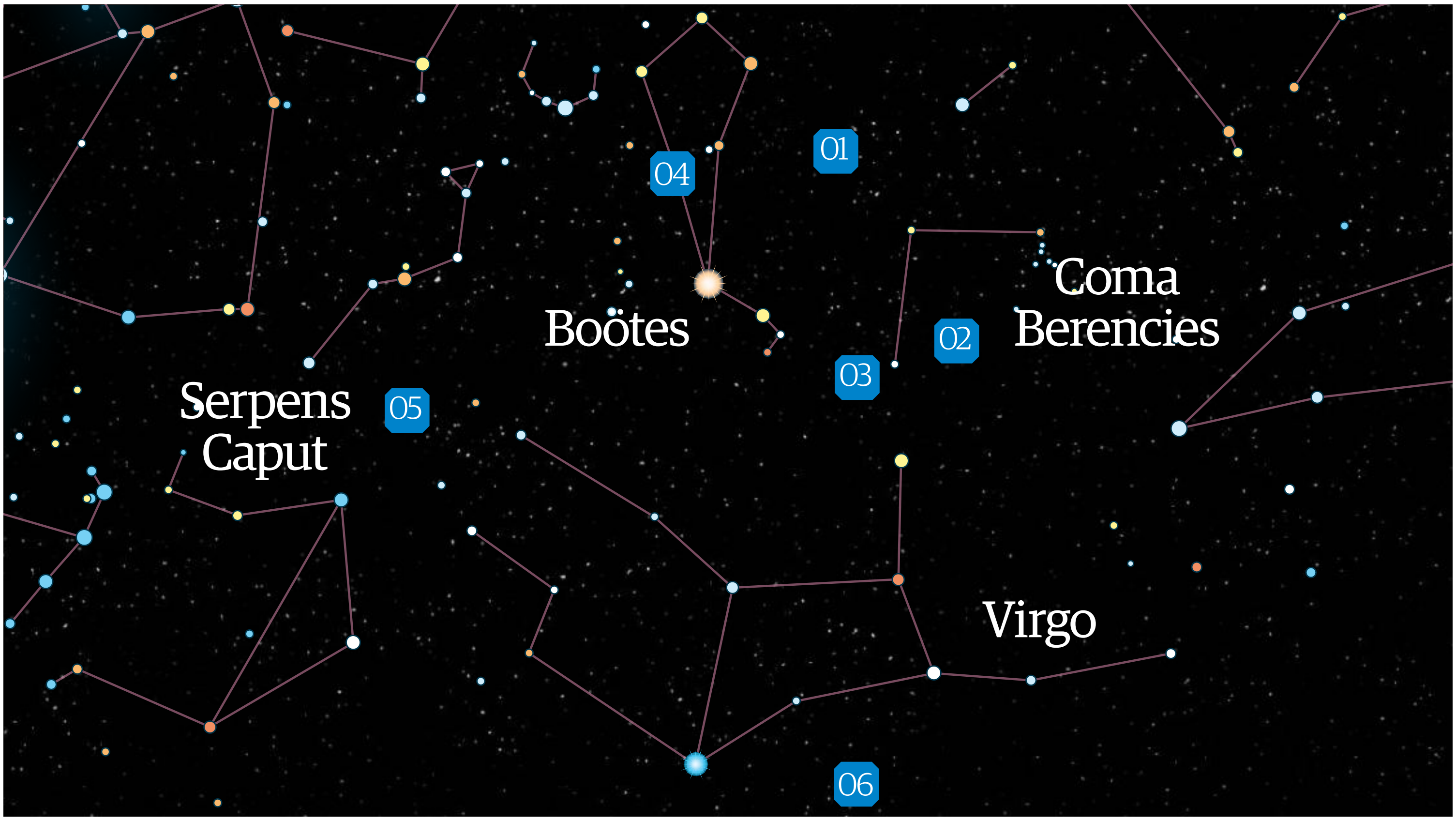
Galaxies and clusters of late spring

This month, a wealth of deep-sky objects for those armed with almost any size telescope are on show

At this time of year the orbit of the Earth around the Sun means that at night we face away from our own Milky Way and look out into the depths of space. This means we can see very distant galaxies, along with globular star clusters, which orbit around the galactic plane, but are often best seen against less crowded star fields. This month, there are also some exquisite double stars of differing colours to split with your telescope too. Here are some suggested targets to turn your instrument towards, although of course there are many, many more to be had if you sweep the skies this spring.



Messier 53



1 Messier 3

This tight stellar collection owns an estimated half a million stars. Four-inch instruments will reveal the bright core, but you'll need an aperture of at least six inches to resolve some of the outer stars.

2 Black Eye Galaxy (M64)

This galaxy has a dark dust lane which makes it look darker near the centre, earning it its name. It's possible to see the spiral through a small telescope, and even good binoculars under very good conditions.

3 Messier 53

A globular cluster with a dense core and some tendrils of straggling stars. Small telescopes will unveil a hazy patch with a large, bright core which is slightly oval in shape.

4 Epsilon Boötis (Izar)

This is a great double star in the constellation of Boötes which is quite tricky to split unless you're observing at a high magnification, with an aperture of at least three-inches required.

5 The Rose Cluster (M5)

A gorgeous globular star cluster with some brighter stars surrounding an intense inner core. You'll require a telescope of at least four-inches to resolve its stars - particularly its brightest members.

6 Sombrero Galaxy (M104)

You'll require a telescope with a large aperture of ten-inches or higher in order to see this galaxy. However, under excellent conditions, a four-inch instrument will hint at Messier 104's dark dust lanes.

Messier 5

How to...

Get the best views of comet C/2016 R2 (PANSTARRS)

On 9 May 2018, the celestial body will make its closest approach to the Sun. Here are some pointers to help you see it...

You'll need:

- ✔ Star chart
- ✔ Binoculars
- ✔ Telescope

Comets are icy bodies which come from the depths of space and, under the action of gravity, hurtle towards our Sun. It is when they are near the Sun that we get to see them in all their glory, often as bright glowing objects with beautiful tails that can seem to stretch across the heavens.

Comets are, however, notoriously unpredictable. We can know, often with some degree of accuracy, where they are going to be, but knowing how bright they might become is much harder to estimate. Comet C/2016 R2 (PANSTARRS) will be no different in this respect. It makes its closest approach to the Sun on 9 May, and we will be able to see it low down in the evening sky at this time. It is estimated to be around magnitude 11 on this date.

This will require the use of binoculars to see it, or preferably a small telescope with low power. However, sometimes, as comets get nearer to the Sun they can go into 'outburst', where they can become thousands of times brighter. Then again, they may not react at all. Outburst is where the heating effect of the Sun can cause the comet to disrupt, ejecting material from its surface. This causes the comet to appear much brighter and produce a much more impressive tail. This depends on a number of factors to happen though and so it can be quite unpredictable. Most estimates of comet brightness are given as if the object is not going to outburst. If it does happen it is very exciting!

> "Knowing how bright a comet might become is much harder to estimate"

As comets are frequently only visible for a short period of time to amateur observers anyway, and are best seen soon after sunset or shortly before dawn, often you only get a narrow window of opportunity to see them. The best time to see Comet C/2016 R2 (PANSTARRS) will be on the evening of the 9 May between 22.15pm and 22.30pm, as this is when it will have its highest elevation. After this time it will drop rapidly in elevation and become harder to see, although it will be available to view both before and after this date and time, and an outburst can happen at any time before, during or after its closest approach to the Sun.

Tips & tricks

Know where to look
You can find the comet between the stars Capella and Menkalinan. Use a star chart to locate it.

Scan with binoculars
Use binoculars to start with, as they will help you locate the comet with your telescope, giving you familiarity of the night sky.

Know your coordinates
You can also use celestial coordinates. Keep up to date on positions by making use of the Internet.

Use a low-power eyepiece
Use a low-power eyepiece with a wide field of view to help track down the comet.

Use filters where necessary
If you live in an area where there's a great deal of artificial light, you can use a light pollution filter to help improve the contrast.

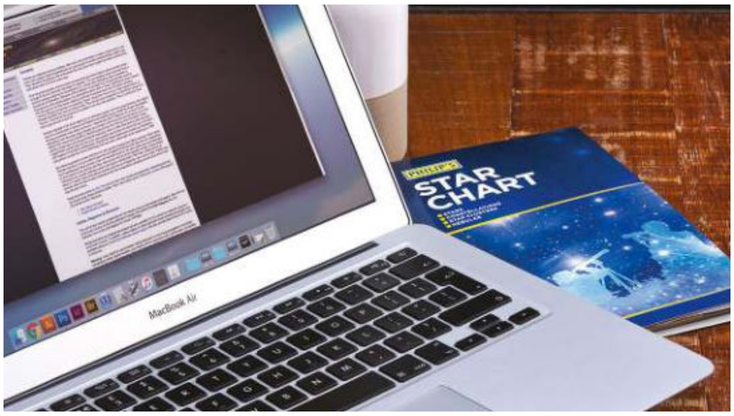
© Damian Peach, Jose J. Chambo

Play up the comet's contrast

A good way to capture a fainter comet can be to imaging them

If you know the area of sky that the comet should be found in, but can't find it with binoculars or a telescope, another method is to use a DSLR camera. You will need a telephoto or zoom lens and a tripod for this. Use the camera manually; having control over the ISO and exposure settings is important. Once you've set the camera up you can take several shots with different settings to see which is best.

Send your photos to
space@spaceanswers.com



1 Track the comet throughout the night
Use the latest information about Comet C2016 R2 (PANSTARRS) from the Internet and a star chart to help you to save time.

2 Set your DSLR to the correct settings
Set your camera's ISO value to 800 up to 1600, depending on your observing conditions. You'll need a higher ISO if conditions aren't great.

3 Get the right exposure
If you are using a tripod, set the exposure time to around ten to 15 seconds. A tripod will ensure that your images are stable enough for decent clarity.

4 Take care with framing
If you are using a zoom lens, try to frame the area of sky to where the comet should be. This will enable the comet's details to be picked out.

5 Take several shots
Take more than one shot while increasing the exposure time and ISO. This will enable you to achieve better, more in-depth results.

6 Study the results
Check the results of your exposures on the viewing screen and see if the comet is clearly visible. Zoom in where appropriate to check the quality.

STARGAZER

The Northern Hemisphere

Summer is on its way with a selection of galaxies and star clusters to be enjoyed into the early hours

With the summer sky bringing with it longer days and shorter nights, the constellations of May are reserved for those willing to stay up until the small hours to capture those stunning night-sky targets.

Observers in the Northern Hemisphere can look forward to gazing at the gems of Canes Venatici (the Hunting Dogs), Centaurus (the Centaur), Coma Berenices (Berenice's Hair) and Virgo (the Virgin), where a stunning selection of galaxies and star clusters are easy pickings with binoculars or telescopes. In particular, the Virgo Cluster is home to the Black Eye Galaxy (Messier 64), and spiral galaxy and brightest member of the Virgo cluster Messier 100, which are a joy to behold on the increasingly warmer evenings.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

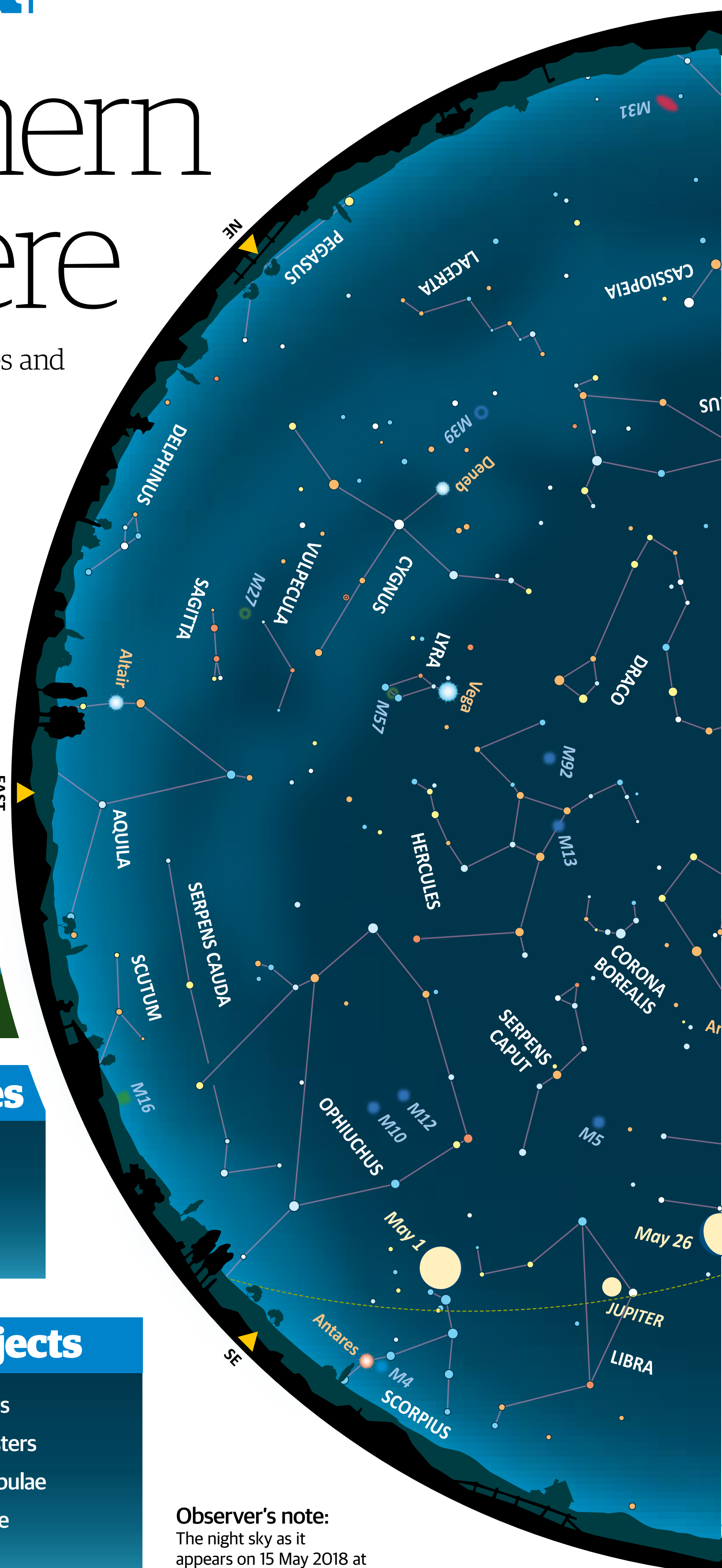
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 15 May 2018 at approximately 10pm (BST).


Galaxy NGC 4651 with its umbrella-shaped stellar streams


Messier 100


Needle Galaxy (NGC 4565)

Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Orion Nebula (M42) & Running Man Nebula (Sh2-279)

Warren Keller

Buckhannon, West Virginia
Equipment: 16-inch RCOS Ritchey-Chrétien, owned by the University of North Carolina PROMPT2 at Star Shadows Remote Observatory at CTIO

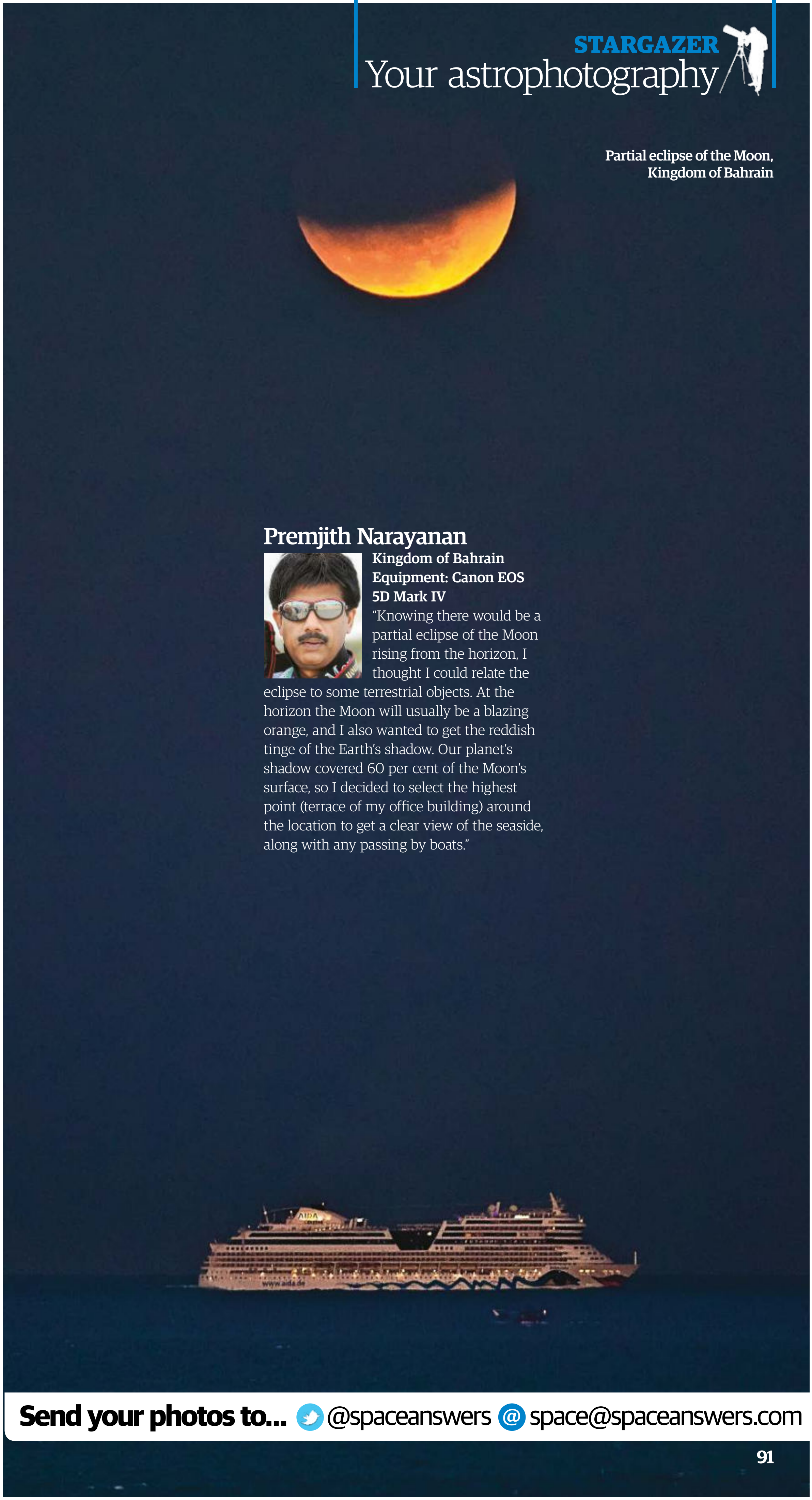
"Here are NGC 6726 and 6727 in the constellation Corona Australis, which comprise the blue reflection in the upper right. The double star BSO 14 on the lower left illuminates the reflection nebula IC 4812. The intriguing, yellowish object above and to the left is variable nebula NGC 6729. Two tiny, but beautiful red Herbig-Haro (HH) objects can be seen to its left, namely HH 98 and 101. Named after astronomers George Herbig and Guillermo Haro, these are jets of gas ejected by young stars at speeds of 100 to 1,000 kilometres (62 to 620 miles) per second. Shock fronts create a glow as the gas is heated by friction and excited by nearby hot stars."

Jaspal Chadha

London, UK
Equipment: Takahashi FSQ-106 quadruplet refractor, QHY128C CMOS, iOptron 45 Pro

"My latest image of the Orion Nebula (M42), with the Running Man Nebula (Sh2-279) within the same field of view. Found in the constellation of Orion, south of Orion's Belt, Messier 42 is 1,344 light-years away. Along the asterism Orion's Sword and just 0.6 degrees north of the Orion Nebula, Sh2-279 is further away from Earth at a distance of 1,500 light years. It includes a selection of different nebulae: bright, reflection and a HII region.

"I am really pleased with this image; I haven't used a colour camera for several years and the results were fantastic, even from the light polluted skies of London."



Partial eclipse of the Moon, Kingdom of Bahrain

Premjith Narayanan

Kingdom of Bahrain
Equipment: Canon EOS 5D Mark IV

"Knowing there would be a partial eclipse of the Moon rising from the horizon, I thought I could relate the eclipse to some terrestrial objects. At the horizon the Moon will usually be a blazing orange, and I also wanted to get the reddish tinge of the Earth's shadow. Our planet's shadow covered 60 per cent of the Moon's surface, so I decided to select the highest point (terrace of my office building) around the location to get a clear view of the seaside, along with any passing by boats."

Send your photos to... @spaceanswers space@spaceanswers.com

Altair GPCAM2 Mono Camera 290M

Shoot in exquisite clarity with Altair Astro's freshly upgraded CMOS

Camera advice

Cost: £259.00 (approx $364.50)
From: Altair Astro
Type: CMOS
Sensor size: 1/20.8 inch

Best for...

- Intermediate
- Medium budget
- Planetary viewing
- Lunar viewing
- Deep-sky objects
- Video astronomy
- Auto guiding

We have reviewed a fair few GPCAM2 astrophotography cameras at **All About Space**, but this month have had the chance to try out Altair Astro's monochrome CMOS. What we've found to be a reoccuring feature during our tests of Altair's GPCAM2 model has been its lightweight yet sturdy design, capable of fitting in 1.25-inch eyepiece slots with ease. We also garnered an appreciation of the high-quality nature of the Sony Exmor CMOS sensors, which - built inside this CMOS - is an IMX290 Mono sensor.

Also included in the package is a USB 2.0 cable capable of quickly relaying data between camera and laptop; an ST4 guide port compatible with most autoguiding systems, including iOptron, Celestron and Sky-Watcher; a 20 and five millimetre telescope adapter and a sensor cover glass with an ultraviolet and infrared blocking filter. All these additions will help you to make the most of a good clear night, but the camera itself is the standout item of the package.

What benefits does this camera have? While its lightweight and compact design - of which accommodates a high-quality sensor - has already been mentioned, it shouldn't be underestimated. The whole camera can fit in your hand, but it is capable of capturing some amazing images. Its casing is of a sturdy metal which will offer good durability, but can get quite hot after long periods of use. If the casing gets too warm to the touch, it may result in lower quality image below its capabilities - something that's much more noticeable in images of fainter and more delicate deep-sky objects. For the most part, the sensor exhibits an impressively high sensitivity reading with a low read for interfering background noise, providing very good imaging results.

"A mono camera can image an object in a much narrower wavelength band"

When it comes to the difference between a colour camera and a mono camera, a colour camera – as the name suggests – is best for shooting an object instantaneously in the Red Blue Green (RBG) filters. A mono camera, however, requires the attachment of separate filters, but can shoot an object in a much narrower wavelength band. This allows for a more selective imaging process, presenting clearer images with even less background noise, but the user would have to have their own filter set, with them requiring separate RBG filters. It also won't hurt to get a hydrogen-alpha filter, too, for a more extensive arsenal of kit. Although this comes at the cost of a longer imaging process – having to replace the filters each time and undergoing the same exposure time regularly – we found the results to be much more rewarding compared to that of a colour camera.

The setting up of this CMOS is a wonderfully painless task. We highly recommend that, prior to imaging, a few minutes should be set aside to install the 'AltairCapture' program, which controls the CMOS camera, handling its exposure settings amongst other features. It doesn't take long and the instructions for its installation are concisely set out in the quick-start instructions page. Its settings will allow the user to alternate between an 8-bit and 12-bit system, as well as adjusting the pixel array. With the choices of a 1920x1080, a 640x480 and a 320x240 pixel array, the frames per second (FPS) rate will be slower with a higher pixel count, leading to a higher quality image. We found this setting to be best suited for imaging 'nearby' Solar System targets such as

GPCAM2 290M is capable of video astronomy and all-sky imaging (if you have a meteor lens)

An incredibly wide range of celestial objects can be imaged using this monochrome camera

Jupiter. As for attaching the camera, it's incredibly straightforward (if you have a 1.25-inch eyepiece holder) thanks to its design. It just needs to be slotted into place and tightened using screws, which is no different from a regular eyepiece.

It's also worth noting at this point that to fully optimise the camera's astrophotography potential, the telescope and mount used is very important. That is, if you wish to bring some amazing, but faint deep-sky objects into sight, you'd have to have a telescope with a low focal ratio and an equatorial mount with a motor drive. Assuming the mount is properly aligned, the telescope can then follow the motion of stars all the way through the night sky until the Sun starts peaking above the horizon. The 290M mono camera is equipped with an autoguiding system, which can be connected to most popular motor drives. This will provide an easier task when it comes to tracking your chosen target and allow for more light intake from the fainter objects you wish to image.

The CMOS was tested out around a time where spring was just around the corner, and that marks the inevitable disappearance of constellations such as Orion (The Hunter) and Monoceros (The Unicorn). To begin with though, we decided to check out the brightest object in the sky: the Moon. With it being just 0.3 per cent off full illumination it was a good opportunity to gain a high-quality image of essentially the full phase. With a Moon filter attached (see 'In the Shops' on page 96 for more on the Moon filter), the image boasted amazing clarity of the lunar surface in black and white. As the Moon doesn't exhibit a wide range of colours, as opposed to a nebula, the emphasis for RGB imaging is not important. In order to harden the task, we did in fact try out a nebula. The Cone Nebula in the constellation Monoceros was a designated target. With the object being tracked using a motorised equatorial mount, we were able to collect as much light as possible. Even with just one black and white image in one filter, the sea of illuminated gas was an impressive sight. With several more images in different filters and much image processing, we were greeted with a breathtaking result.

We were extremely impressed with our experience of Altair Astro's GPCAM2 290M. Having previously reviewed its cousin, the 290 Colour camera, we can see that there are pros and cons between the two. With the colour camera you don't need to worry about changing filters, and this leads to a quicker and more efficient astrophotography process. On the other side of the coin, the monochrome camera offers the opportunity for a more advanced and selective imaging experience, and this will bring the more hidden astronomy features to life. With the monochrome having a more advanced sensor, it is probably much more suited to conduct more advanced astrophotography. However, we can confidently say that Altair's astrophotography cameras are excellent when it comes to creating great quality images with a hand-sized camera, and this CMOS is of no exception.

Its USB cable relays data at a decent rate, allowing for frequent frame updates

The IMX290 Mono CMOS sensor boasts a high sensitivity with very little background noise read

WIN!

WIN A VIXEN 'GRAB-AND-GO' BUNDLE

This supreme bundle will provide all the tools you need to enjoy the majesty of the night sky

WORTH £788

What more do you need for observing some fantastic celestial beauties then this incredible Vixen bundle, supplied by Opticron? With a lightweight, compact, yet very powerful Maksutov-Cassegrain telescope, a versatile and simple Porta II alt-azimuth mount and a pair of Plössl eyepieces (4mm and 25mm), you have everything you need to pick up your equipment and head straight for the nearest dark-sky location.

The telescope will bring amazing clarity to an array of objects, including the Moon, our fellow planets within the Solar System and even some of the brighter deep-sky objects. With an easily manoeuvrable alt-azimuth mount, it will not take you long to set up and get started on a night of breathtaking views. With two eyepieces that pride themselves on offering flat and clear views with good colour correction, the chance to win a bundle such as this should not go amiss.

To be in with a chance of winning, all you have to do is answer this question:

11 May 2018 marks the 100th birthday for which famous American theoretical physicist?

A: Julian Schwinger

B: Robert Oppenheimer

C: Richard Feynman

opticron

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Congratulations to Paul Oldman, who is the winner of the Sky-Watcher Skymax-102

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The latest books, apps, software, tech and accessories for space and astronomy fans alike

1 Book NASA Skylab Owners' Workshop Manual

Cost: £22.99 (approx. $32.60) **From:** Haynes Publishing

This manual covering the full workings of NASA's first ever space station, Skylab, is precise, thorough and informative, consistent with the quality we have come to expect from Haynes manuals.

An amazing piece of engineering and technological genius, Skylab orbited our planet between 1973 and 1979. What the book's author - David Baker - covers is so much more than its years in operation, and way more than just the basics of its layout. It covers everything from the early concept design through to the eventual premature decline, which occurred due to unforeseen solar activity. This book is packed full of facts, figures and many illustrations, leaving no stone unturned.

With this book essentially being an encyclopedia of NASA's Skylab, it's a pleasant read for a space enthusiast looking for a story or a narrative to follow. Not only that, but with almost 200-pages of text and photographs, this book will delight those looking for a revolutionary memento from space exploration's past and who want to learn more about the intricate details of Skylab's operation.

2 Accessories Celestron Firstscope Accessory Kit

Cost: £19.00 (approx. $27.00) **From:** David Hinds Ltd.

The aim of this accessory kit is to enhance your view of the night sky, providing enhanced sights with impressive contrast. What is included is very generous and good quality for your money: a 12.5 millimetre (half an inch) eyepiece, a six millimetre (0.2 inch) eyepiece, a 5x24 finderscope, a CD-ROM for 'The SkyX', a nylon carrying bag as well as a Moon filter featured below, which alone is over half the price of this full kit.

The 12 and six millimetre eyepieces, giving a magnification of 24 and 50x respectively, allow an astronomer to mix up their options when it comes to tackling different celestial objects. We were also impressed with The SkyX CD-ROM, as it is available to install on PCs including Windows 7, XP and Vista and Mac computers. The program not only provides you with a fine computer planetarium, but you can also print out the star charts in preparation for an efficient night of observing. The only possible confliction is that you'd have to check if the finderscope is compatible with the telescope you wish to pair it with. Boasting superior quality, we recommend this product to anyone who wants to expand their astronomy 'tool kit' whether they're new to observing or are seasoned astronomers.

3 Accessories Celestron Moon Filter

Cost: £10.00 (approx. $14.00) **From:** David Hinds Ltd.

There is no doubt that if the Moon is out, many amateur astronomers will begin their night focusing on our own natural satellite. This amazing object, covered in craters and darkened surface seas, known as 'mares', provides an amazing sight to even the most unseasoned eye. However, the Moon reflects a large amount of light, especially at full Moon, and this can cause a slight issue when our eyes are trying to resolve the finer details of its surface.

In the same way a pair of sunglasses will dim incoming light, Celestron's Moon filter will help you to improve your views of the lunar surface with ease - simply by attaching the filter on to any 1.25-inch eyepiece, which is incredibly straightforward. After testing the filter, we were impressed by the improved contrast of the Moon when using it, which made a pleasant and noticeable difference. A handy accessory for any lunar viewings, it should also be clearly understood that this filter is for use in observing the Moon only, and for any solar observations.

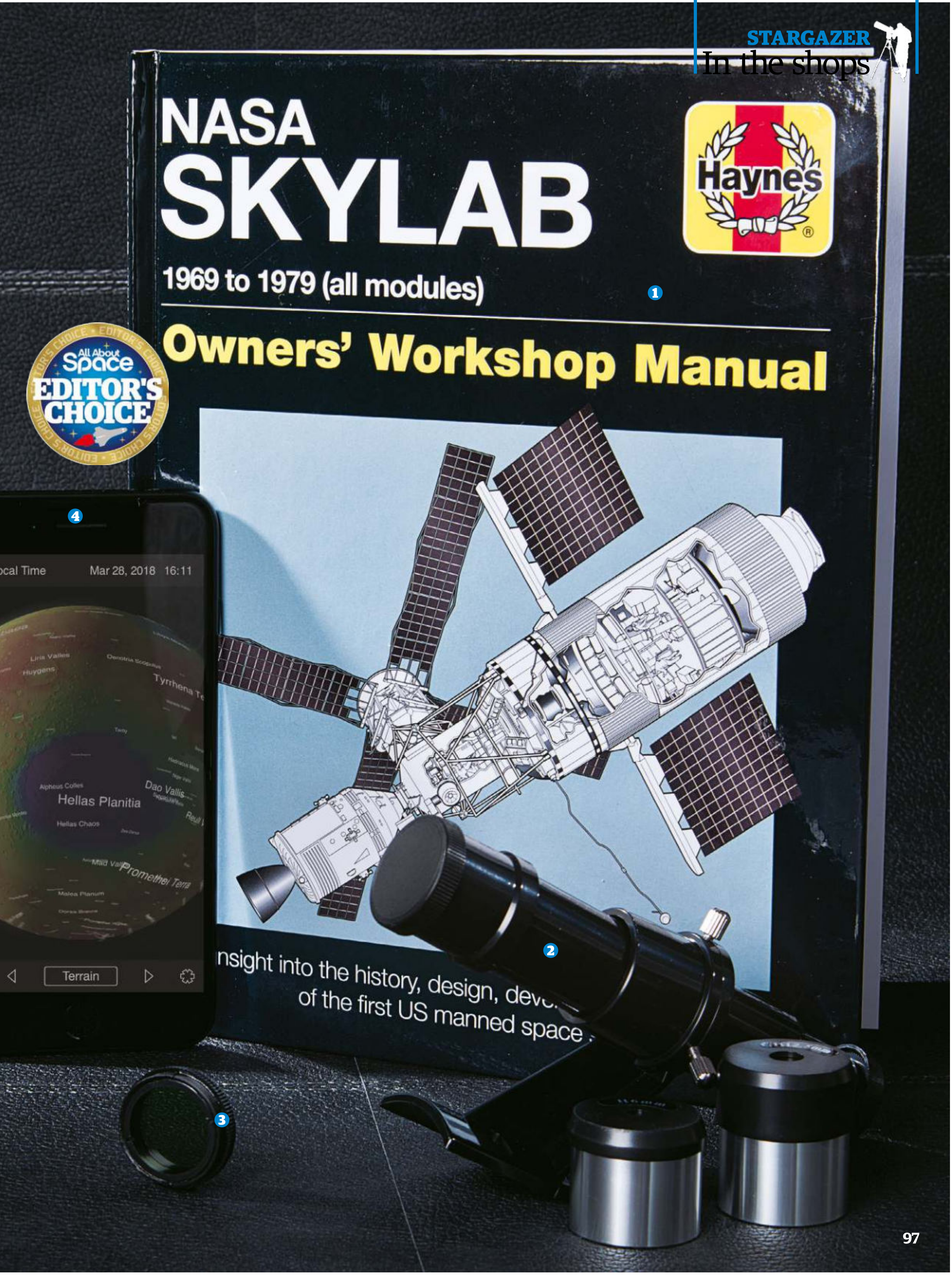
4 App Mars Globe

Cost: Free **For:** iOS

With this app you'll be able to take your own tour of the Red Planet thanks to a combination of satellite images of the surface and a navigation system controlled by your fingertips.

At first glance, Mars Globe may seem fairly simplistic, but after using it we were quite impressed with what it had to offer, given the fact it is a free app. It allows you to head to different craters, dormant volcanoes, Martian probes' landing sites and the 'albedo' features, which are large Martian areas that show a high contrast in brightness and darkness. Not only does it show the Red Planet's features, but it also supplies a short description of each and offers links to further information and images - an essential feature for the more inquisitive minds.

Overall, the app is great for going on a tour of Mars and learning about its surface features. However, it is just limited to the Red Planet, which means it may not take long before you've seen what you've wanted to observe and want to move on to another world.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1969 to 1979 (all modules)
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Mar 28, 2018 16:11
Hellas Planitia
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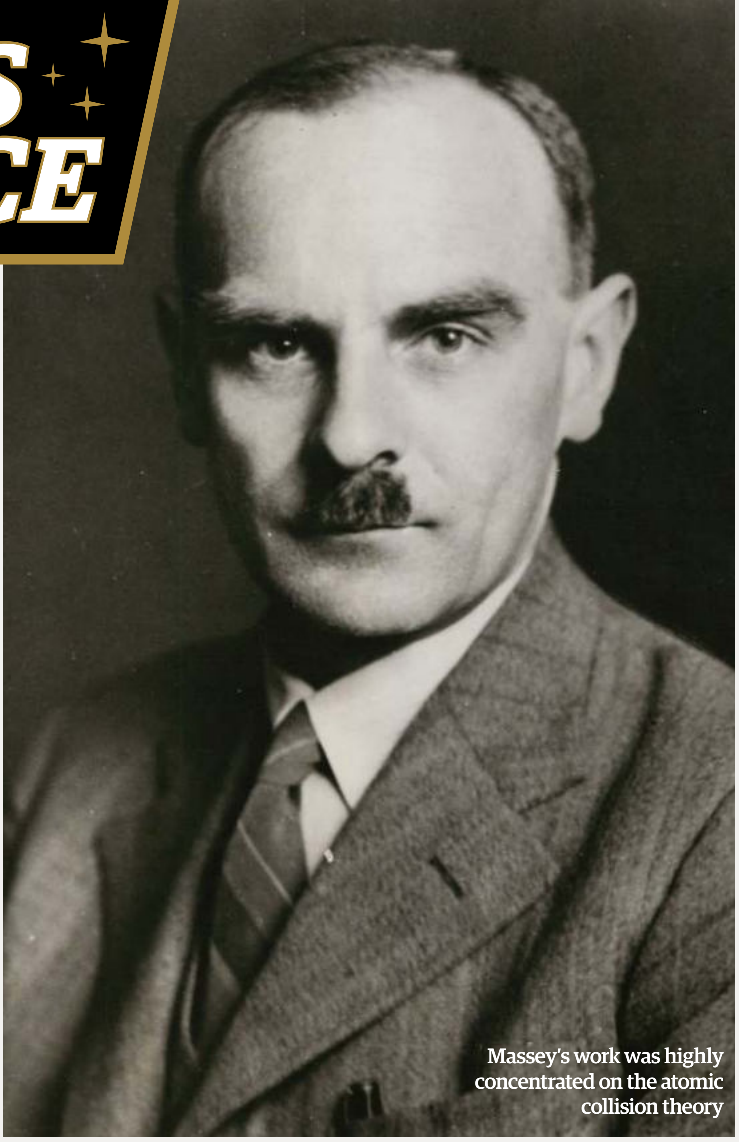
1
2
3
4

HEROES OF SPACE

Sir Harrie Massey

His affection for physics and maths reaped benefits for the entire world



Massey's work was highly concentrated on the atomic collision theory

© Keystone Pictures USA / Alamy Stock Photo

Sir Harrie Stewart Wilson Massey FRS, the Australian mathematical physicist, dedicated his life's work to understanding the behaviour of subatomic particles. In a time when the theory of quantum mechanics was being born, Massey's contributions, particularly regarding collision theory, were incredibly influential and very well received among the scientific community.

Born on 16 May 1908 in Invermay, Victoria, Australia, Massey excelled throughout his education, and was able to get into Melbourne University as part of a government scholarship at the age of just 16. While at Melbourne University he gained a Bachelor of Science (BSc) in Physics, a Bachelor of Arts (BA) in Pure and Applied Mathematics and a Master of Science (MSc) degree in Physics, as there was no PhD offered at the time. All of this occurred over the span of four years.

In August 1929, Massey was awarded the University's Aitchison travelling scholarship, which led him to the esteemed Cavendish Laboratory in Cambridge, England. The Nobel Laureate Ernest Rutherford was leading the institution at the time, a man who is widely referred to as the 'Father of Nuclear Physics'. The year 1932 came and Massey completed his PhD on 'The Collisions of Material Particles'.

Massey was producing scientific paper publications at a incredibly impressive rate while at Cambridge, and in 1933 he collaborated with future Nobel Prize-winner Sir Nevill Mott on the book titled *Theory of Atomic Collisions*. This book became extremely popular, as it outlined different ways of treating the collisions of quantum particles. In the same year, Massey departed Cambridge and became an independent lecturer in Mathematical Physics at the Queen's University of Belfast, Northern Ireland.

At Queen's University Massey proved to be an excellent lecturer while also continuing to write many publications about collision theory and negative ions. After half a decade, the University College London (UCL) requested that he became their Goldsmid professor, to which he obliged. However, his tenure was cut short, as it wasn't long after the Second World War broke out and the United Kingdom required his intelligence and ingenuity in order to defend the country's people.

The efforts of Massey and his colleagues led to a clever invention that protected British ships against magnetic mines. Eventually, Massey ended up as the chief scientist at the Mine Design Department in Havant, Hampshire, England. His efforts were needed elsewhere, though, as Massey then travelled to Berkley, California, United States to be part of a team of British scientists that contributed to the development of the atomic bomb, also known as the Manhattan Project. On his eventual return in 1945, Massey went back to the mathematics department of a damaged UCL.

He then became the Quain Professor of Physics in 1950, where he enjoyed the latter end of his fruitful and incredible career, prior to retiring in 1975. Upon reflection of his career and his contributions to science, there is no doubt that Massey should be considered a Hero of Space, as his work on subatomic particles has helped scientists to understand the elusive nature of quantum particles to this very day. This is shown in his honours, such as the Hughes Medal awarded in 1955, which has been won by famous scientists such as Max Born, Enrico Fermi and Stephen Hawking. Arguably the most prestigious award he was presented was his Royal Medal, awarded in 1958. Massey passed away in 1983, aged 75.

> "Massey was producing scientific paper publications at an incredibly impressive rate"

All About Space

Future PLC Richmond House, 33 Richmond Hill Bournemouth, Dorset, BH2 6EZ

Editorial
Editor **Gemma Lavender**
gemma.lavender@futurenet.com
01202 586209
Art Editor **Jonathan Wells**
Staff Writer **Lee Cavendish**
Production Editor **Nikole Robinson**
Group Editor in Chief **James Hoare**
Senior Art Editor **Duncan Crook**

Contributors
Stuart Atkinson, Abigail Beall, Ninian Boyle, David Crookes, Ian Evenden, Robin Hague, Giles Sparrow, Colin Stuart, Libby Plummer

Cover images
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Advertising
Media packs are available on request
Commercial Director **Clare Dove**
clare.dove@futurenet.com
Regional Advertising Director **Mark Wright**
mark.wright@futurenet.com
Account Director **Andy Baker**
andy.baker@futurenet.com
01225 687 520
Media Sales Executive **John Butters**
john.butters@futurenet.com
01225 687 170

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Tel +44 (0)1225 442 244